1865

# REPORT OF THE COMMISSION

APPOINTED BY AUTHORITY OF THE

## CITY COUNCIL

TO TAKE INTO CONSIDERATION THE BEST METHOD
OF OBTAINING AN ABUNDANT

# SUPPLY OF PURE WATER

FOR THE

## CITY OF CINCINNATI.

CINCINNATI:
TIMES STEAM BOOK AND JOB PRINTING OFFICE.
1865.

# REPORT OF THE COMMISSION.

CITY HALL, CINCINNATI, JULY, 1865.

*To the Hon. City Council of the City of Cincinnati:*

GENTLEMEN: At a meeting of your honorable body, held October 20th, 1864, it was "*Resolved,* That the Trustees of the Water Works be invited to meet with the Mayor of the City and a Committee of three members of the City Council, for the purpose of forming a Commission to take into consideration the best method of obtaining an abundant supply of pure and wholesome water for the City, and that said Commission be and they are hereby authorized to institute and carry out all requisite preliminary surveys and investigations for ascertaining the most economical and practicable mode of supplying our City with pure water, and report to Council at as early a day as possible"—and the following members were appointed, viz: R. B. Moore, Wm. P. Wiltsee and George F. Davis; to which were added the Hon. T. H. Weasner, President of Council, and A. W. Gilbert, City Civil Engineer.

On the first of November the Committee thus constituted met and organized, and proceeded to take the necessary steps to carry out the objects of the resolution. In order to do this, the Commission deemed it of the first importance to obtain the services of a competent and reliable civil and hydraulic engineer, for the purpose of making a thorough examination of the whole question of water supply for our City.

At the meeting, November 10th, a sub-committee was appointed, to correspond with eminent gentlemen in other cities, with reference to the employment of some suitable person to conduct the examinations. This Committee, after correspond-

ing with gentlemen connected with the Water Works of New York, Brooklyn, Boston, Albany, Philadelphia, Chicago and Baltimore, reported in favor of obtaining the services of James P. Kirkwood, of Brooklyn, New York.

At the meeting, February 2d, 1865, it was decided to send a Committee to Brooklyn and New York City, with a view of a personal interview with Mr. Kirkwood, and also Mr. Alfred W. Craven, Chief Engineer of the Croton Aqueduct Department of the City of New York.

The Committee, after receiving the written testimony of some of the most eminent professional gentlemen residing in Boston, New York, Brooklyn and Chicago, and seeing and conversing with Mr. Alfred Craven, of the Croton Aqueduct Department of New York City, and Moses Lane, Esq., Chief Engineer of the Brooklyn Water Works, addressed a note to Mr. Kirkwood, who was at Montreal, Canada, at the time of their visit to New York, and engaged him to make the desired examinations, and so reported to the Committee in March, 1865.

In April Mr. Kirkwood arrived, and immediately proceeded to make the necessary surveys and examinations, which have been vigorously pushed forward and completed in a speedy and satisfactory manner.

The subject of the best mode of supplying a large city with water is one of no ordinary magnitude and importance, and the Commission have undertaken this matter with a good deal of hesitation and a deep sense of the responsibility resting upon them. It is a subject surrounded by many embarrassing circumstances, and if, in this report of facts and conclusions, they have failed to justify your expectations or wishes, they are in hopes the delinquency will be attributed rather to defect in capacity than to any want of zeal on their part.

It is the experience of all cities of modern times in arranging for water works, that provision for a very liberal supply of water should be made at the outset, and that an *abundant* sup-

ply of *pure* water is worthy of almost any expenditure of energy and means.

The ancients ever regarded a supply of pure water in abundance, not only as one of the greatest blessings, but as indispensable. Witness the great and costly works of the Romans to supply the "Eternal City." The aggregate flow of water into Rome, shortly after the Christian era, has been estimated at three hundred and fifty millions of gallons daily, equal to a daily supply of two hundred and ninety-two gallons to each inhabitant. Their aqueducts were of the most magnificent and durable character, the ruins of which are objects of curiosity and wonder to this day. One aqueduct, the *Aqua Claudia*, conveyed to the city, daily, sixty-five millions of gallons, and formed a subterranean stream of thirty miles in length, a portion of which was supported on arches through an extent of seven miles. Two other channels, one of forty-three miles, and one of sixty-eight miles in length, conveyed the waters of the Anio to the city, one of which formed one continuous series of arches six and a half miles long, many of which were upward of one hundred feet in hight. Compared with these and other similar works of the ancients, the Cochituate, the Croton, the Fairmount, or the Brooklyn works, sink into insignificance.

Modern cities, however, are beginning to appreciate the wisdom of the ancients in the matter of obtaining a bountiful supply of pure water, and the theory that water can not be wasted in large cities, when an abundance can be had, is fast receiving the public sanction. Every gallon which passes through a sewer or a gutter is a purifier, and if public baths could be constructed throughout the city, and public fountains could pour forth their streams in every elevation and depression, the health of the inhabitants of the city would be promoted to a greater extent, probably, than by the adoption of any other positive expedient which human ingenuity could devise.

Liberal as provision was thought to have been made by the cities of Boston, New York and Philadelphia, at the time of

the establishment of their works, they have each found it necessary, at certain seasons, to husband their resources, and reports from those cities show that an increase of consumption of water is each year greater in proportion than the increase of population.

In presenting these facts, the Commission have in view a single consideration which they desire to impress forcibly upon the minds of Council and people, and that is, that in undertaking any new works we should be sure that we do so upon such a scale as will insure a prompt and certain delivery of that most valuable and indispensable article for a largely increased population and a largely increased demand.

The question of the *source* of supply for our city has been a vexed one in our community for many years. Some of the present Commission were of a Committee of Council, some five years ago, to take into consideration the expediency and practicability of bringing the waters of Mad river and the Great Miami to this city by gravity, when an analysis of these waters showed that they were much inferior to water obtained from the Ohio river, and that project was abandoned.

It has been thought by many of our citizens, however, that water obtained from gathering grounds, as at Albany and Brooklyn, New York, would not be liable to the objections found to exist in that of the principal streams of the regions surrounding our city; and the Commission were particularly anxious that the subject of obtaining water by gravity, from the drainage of the rain-fall of the surrounding country, within reasonable limits of the city, should be thoroughly investigated and conclusively settled, and so instructed their Engineer—not wishing to limit him in time or expense, or spare any pains in making the most searching investigations.

It will be seen by an examination of the report of Mr. Kirkwood, that water obtained in this manner in the vicinity of our city, is open to the same objections as that of the streams mentioned, owing to the presence of large quantities of lime, with

which all the soil in our vicinity is so highly charged. It is found that, under the most favorable circumstances, the water obtained from the region of country drained by the Miamis is much harder and contains a much larger proportion of lime than the water of the Ohio river.

The value of soft water, in contradistinction to that of hard water, has been very thoroughly investigated in England by the "General Board of Health Commission," appointed by Parliament, the reports of which contain the testimony of the most eminent chemists and engineers, and is well understood and definitely settled. Doctor Thomas Clarke, one of the most eminent chemists of the United Kingdom, testified at great length before this Commission in regard to this matter; and his evidence, corroborated by that of others, fixes, without a doubt, the inestimable value of soft over hard limestone water, both as regards health and economy. It is hardly necessary to go into any detail of this matter here.

We regard the question, therefore, as to the source of supply for our city as definitely settled for all time, and that the Ohio river is the only means from whence this city should derive her supply of water.

It is now to be determined how, when, and in what manner we shall get our water from the river. It is admitted by all that the location of the present works is objectionable, and that we need more reservoir room, and that the water as now obtained from the river, a large portion of the year, needs filtering to render it clear and free from the sedimentary matter held in solution when in its turbid state. All these points are urged by Mr. Kirkwood, and are provided for in his examinations and report.

The location of the works, as made by Mr. Kirkwood, are as high up the river as can well be obtained without crossing the Little Miami, which we do not think worth while to advocate now. Perhaps fifty or one hundred years hence the extensions of the city may be such as will demand the then city author-

ities to carry their works beyond the Miami river, and locate the reservoir on the hills east of that stream, and even then the reservoir, as now proposed, will doubtless be retained as part of the system for supplying the city with water.

The site selected for the distributing reservoir is admirably adapted for the purpose, being away from any present or probable thoroughfare of travel, always open to a free circulation of air, free from any proximate cause of comtamination, and in a remarkably safe and secure position — the lands being on an elevation such as commands one of the finest views of the river and city in our vicinity, and the spot will afford, when finished, a very pleasant place of resort for our citizens.

We would recommend that in securing the site for the reservoir, additional ground be obtained, in order to make for our citizens a place for recreation, as is now done at Boston, New York, Philadelphia, Albany and other cities.

The location of the settling reservoirs and filter beds, on the bank of the river at Pendleton, is a convenient one, and well adapted to the object to be obtained.

The main, or storage reservoir, will require thirty-nine acres of land, and have a water surface of about twenty-five acres, and is estimated to contain one hundred and fifty-two millions, one hundred and twenty thousand U. S. gallons.

The ground proposed to be occupied by the settling basins or filter beds is about forty-five acres.

The estimates of the Engineer are given in detail in the appendix to his report, and include the cost of

Three settling reservoirs of about six and a half acres water surface each;

Two filter beds;

One storage reservoir of twenty-five acres water surface;

Two low service and two high service engines, with engine houses all complete;

Force mains and supply mains to the city;

Land, damages, and fencing, and an auxiliary pumping engine, house and reservoir for the high lands of Walnut Hills, Mount Auburn, &c., making the whole cost a grand total of $3,038,214.07.

In conclusion, we would urge that steps be immediately taken by Council to obtain possession of the ground for the new works and reservoir. We are of the opinion that by judicious management the ground can be obtained and the works built without subjecting our citizens to a burdensome tax. We do not propose or favor the expenditure of large sums of money immediately, only that a commencement shall be made, and that we work according to a well arranged and thoroughly matured plan, as our means and circumstances may warrant.

The present works are expected to answer for several years to come, and by distributing the large sum necessary to obtain works of the character proposed, and such as will be required, through a period of several years, the annual amount to be paid will scarcely be felt by our citizens.

All of which is respectfully submitted,

L. A. HARRIS,
THOMAS H. WEASNER,
D. T. WOODROW,
*HENRY PEARCE,
GEO. F. DAVIS,
WILLIAM P. WILTSEE,
†CHARLES BROWN,
A. W. GILBERT.
*Trustees of the Water Works.*

* Elected in April, in place of Jos. Torrence, whose term of office expired.

† Appointed by Council, vice R. B. Moore, Esq., whose term of office as member of Council expired in April last.

NOTE.—Mr. Kessler, one of the Trustees of the Water Works, declines signing the Report, upon the ground that he does not recognize the necessity of expending such a large amount of money for new Works; and that, in his opinion, the present Works will, with an additional reservoir, answer all reasonable requirements for many years to come.

Land, damages, and engine and an auxiliary pumping engine, house and reservoir, for the high lands of Walnut Hills, Mount Auburn, &c., making the whole cost a grand total of $3,088,214.07.

In conclusion, we would urge that steps be immediately taken by Council to obtain possession of the ground for the new works and reservoir. We are of the opinion that by judicious management the ground can be obtained and the works built without subjecting our citizens to a large debt and tax. We do not propose, or favor, the expenditure of large sums of money immediately, only that a commencement shall be made, and that we work according to a well arranged and thoroughly matured plan, as our means and circumstances may warrant.

The present works are expected to answer our wants for years to come, and by that time the large sums necessary to extend works of the character proposed, and such as will be required, through a period of several years, the annual amount to be paid will scarcely be felt by our citizens.

All of which is most respectfully submitted,

R. M. BISHOP,
THOMAS H. WEASNER,
JOHN WOODROW, } Trustees of Water Works.
HENRY PEARCE,
JOHN C. DAVIS,
WILLIAM S. WHEELER,
RICHARD HAYS,
[illegible]

* Elected in April, in place of J. A. Tarrant, whose term of service expired.

† Appointed by Council, vice R. F. Wilson, Esq., whose [illegible] of [illegible] expired in April last.

Note.—The [illegible] of the Trustees of the Water Works for the ensuing [illegible] is, that it shall be [illegible] the ground [illegible] the expenditure of a large amount of money for new Works, and the [illegible], the present Works will, with [illegible] answer [illegible] for many years to come.

# CINCINNATI

# WATER SUPPLY COMMISSION

## OF 1865.

## REPORT UPON THE PROPOSED MODE OF SUPPLY

BY

JAMES P. KIRKWOOD,
Civil Engineer.

JULY 3, 1865.

# REPORT OF THE ENGINEER.

CINCINNATI, OHIO, JULY 3D, 1865.

TO MAYOR L. A. HARRIS, *President, and to the Members of the Commission for the Extension of the Water Supply of Cincinnati:*

GENTLEMEN:—In accordance with your invitation to examine the whole question of the water supply of your city, and to give my views as to the best mode of increasing and perfecting that supply, I have been engaged during the last three months in making such surveys and examinations as the circumstances seem to call for; and I now beg to report accordingly.

Your letter of invitation indicates, in general terms, the duties required of me; but as the resolutions passed by your Board, on the — day of ——— 1865, embrace the same topics, and are more explicit, I will give them here, as best explaining the character of the examination desired by you.

They are as follows:

"1. *Resolved*—As the opinion of this Commission, that in order to ascertain the most economical and practical mode of supplying our city with pure water, it is necessary to take into consideration and examine carefully the whole subject of water supply, with the view: *First*, of ascertaining the cost and feasability of supplying our city with water from gathering grounds, and by gravity, with a series of storage basins or reservoirs connected with said gathering ground; as also: *Secondly*, the obtaining of an abundant supply from the Ohio river by means of pumping by steam, with large reservoirs connected therewith, for the purpose of forming storage basins.

"2. *Resolved, further*—That no scheme will be considered as fulfilling the conditions of an 'abundant supply' that does not provide for the delivery of at least 30,000,000 (United States standard) gallons of water daily, throughout the year, and that further provision shall be made for increasing this daily supply, as may be demanded by an increasing population, so as to furnish at all times a supply of water at the rate of one hundred United States standard gallons to each inhabitant of the city."

These resolutions have formed my written instructions.

The gathering grounds within reach of the city have not been so minutely explored as the tone of the resolutions would have warranted, but they have been sufficiently so, to enable me to understand their extent, and to ascertain the capabilities of certain of the smaller streams which have been looked to as offering peculiar advantages in this connection.

The water supply of the city by what is called "gravitation," instead of by pumping power, is not necessarily less costly than that by machinery, although many view it in that light, but it is more simple in its action, more easily superintended and maintained by ordinary intelligence, and does not admit of the vexed discussions in regard to the different forms of machinery, which perplex and delay, very prejudicially sometimes, the timeous extension of the pumping power.

In the other case, the hesitation which questions in regard to the best form of machinery always produce, has operated to render the mode of supply by gravitation more popular. But the difficulty is one which will be less and less felt as the public mind becomes more familiar with the subject.

A scheme of supply by gravitation involves, necessarily, an extent of constructive preparation which shall satisfy the wants of the particular city for some thirty to forty years, as regards the size of conduit. At all events, a second conduit not being thought of by the generation which supplies the first.

Where pumping power is used, additions can be conveniently made every five or ten years, so far as the machinery is con-

cerned, and the first cost of the work will therefore, to this extent, be more fairly distributed.

With proper attention, the pumping power may always be kept so well in advance of the demands upon it, as to render its operation as reliable in every way as the conduit under the system of gravitation. In either case, constant attention is necessary to the proper maintenance and repair of the works. In the gravitation scheme, neglect is not so readily perceptible, nor its evil consequences, like defective machinery, so quickly felt by the consumer, but with proper care and foresight, the one may always be made as certain in its deliveries as the other.

The simplicity of operation and of supervision, will always, however, make the mode of supply by gravitation the most desirable. But the character of the water to be supplied demands your first attention, the mode of supply being in itself of comparative secondary importance.

Cincinnati is situated in the center of a limestone region of country, through which the Ohio river, in its course towards the South, carries in its channel the waters of the northern parts of New York, Virginia, and Pensylvania, collected from districts of country where the geological formation is much of it primitive and mountainous, and at all events devoid of the limestones or other rocks, which render the waters escaping from them objectionable for domestic use.

The waters of the river, in this upper section of its course, are quite soft. Below Concord they enter upon the limestone basin, in which the city of Cincinnati is situated, and after mingling with the rivers which rise in that basin, the Ohio water becomes to a certain extent deteriorated, not sufficiently so, however, as to make rain water in that sense preferable and necessary, but yet decidedly harder than the New York, Boston or Brooklyn waters. I use the terms hardness and softness as expressive of important characteristics well understood. The cleanliness, limpidity, or purity of the water as regards organic matter is another element of the question.

The water of the Ohio river, at Cincinnati, becomes thus a mixture of soft and hard water. The region from which the soft water is gathered, approximates to an area of 69,743 square miles, and the limestone region which furnishes the hard water, approximates to an area of 7,955 square miles, being as nine to one nearly.

The water of the river, at Cincinnati, varies slightly throughout the year, according as the contributions from the limestone basin, or those above and beyond its influence predominate.

The accompanying sketch of the country north of Cincinnati, includes the entire valleys of the Great Miami and the Little Miami rivers, with the valleys of the intervening smaller streams. The portions of the gathering grounds of these rivers which could be made available for the supply of your city by gravitation, are there defined by color. The portions of certain of the tributaries of these, and of Millcreek, which are of sufficient extent to be available on the same plan, are also defined by color.

The waters of all these streams are gathered from a limestone district of country, unmixed with the waters of any other geological formation. They might therefore be expected to be harder, and in that sense less desirable than the water of the Ohio river, and this turns out to be the case.

In 1853, a minute analysis was made by Professor Locke, of specimens of the waters of the Miami rivers, and of the Ohio river. The result of this investigation seems to have been to satisfy the public mind, at the time, that the Ohio water was decidedly preferable to that of either the Great Miami or the Little Miami. It has been contended, however, that if the waters of certain of the smaller tributaries of the Miamis, whose banks toward their sources are steep, could be collected in impounding reservoirs, the character of the water thus gathered would be softer than that of the main river, by reason of

the rain water flowing off rapidly from the steep hill sides, without penetrating the lime rocks underneath.

To a certain extent this is true, the waters of these creeks or brooks when in flood immediately after heavy rains, are less objectionable in character than when low, but all such as we have examined, are even then much more objectionable than that of the Ohio river, as respects the amount of lime held in solution. To ascertain the comparative character of the waters of these brooks, specimens of them have been examined by Dr. E. S. Wayne, chemist, of this city. I have also examined them by Dr. Clark's soap test, procured from London for that purpose. This test has been so much used, and is now so well known, as to make its indications a very reliable guide as a measure of comparison.

To ascertain the points on these brooks whence the water could be drawn to the city by a gravitation scheme, it was necessary to carry levels up their valleys; the point sought in each case, was based on an assumed height of reservoir in or near the city, of one hundred and eighty feet above low water of the Ohio river, and upon an inclination of conduit of one foot per mile. The length of conduit assumed, was not measured, as this course would have involved tedious and expensive surveys, but was taken from the distances which the canal or roads indicated. To have taken the water below the point where the stream could be tapped, would have been unsatisfactory. It was therefore necessary to approximate to that point, and the levels of the different reaches of the canal on one side and of the railroad on the other, facilitated our labors in this respect.

The following named streams were examined, but no specimens collected of their waters, the drainage area in each case above the points where they could be tapped, being too small to warrant the construction of any works upon them.

Lick Run, entering Millcreek.
West Fork of Millcreek.
Ross Run, entering Millcreek.
East Branch of Millcreek.
Duck creek, entering the Little Miami river.
Sycamore creek, entering the Little Miami river.

The following named streams presented fair prospects for the collection of water, as regards quantity.

| | Situation of Connecting Point. | | Drainage Area. |
|---|---|---|---|
| | Elevation above low water at Cincinnati. | Distance from Cincinnati in Miles. | Square Miles. |
| First—The Great Miami Valley. | | | |
| Clear creek, | 270 | 49 | 39 90-100 |
| Gregory creek, | 220 | 38 | 16 |
| Dicks creek, below Middletown, was found to be very unfavorable for reservoirs. | | | |
| Second—Little Miami Valley. | | | |
| Muddy creek, | 222 | 32 | 10 25-100 |
| Turtle creek, | 220 | 33 | 27 |
| Third—Valley of Millcreek. | | | |
| West Branch of Millcreek, | 196 | 16 | 28 50-100 |

In the following table, the merits of the waters of these streams as regards hardness, are indicated. My own examinations of them by Dr. Clark's test were carefully repeated. Specimens of the waters were submitted to the examination of Dr. E. S. Wayne, chemist, of this city. His report will be found in the appendix. The results of Dr. Wayne's examinations are embodied in this table. There are some anomalies in these, which I cannot explain. My observations by the soap test correspond nearly with Dr. Wayne's for Clear creek, the Ohio river, and Millcreek, but differ from his more or less for the others.

*Results of the examinations of certain waters in the neighborhood of Cincinnati to ascertain their relative hardness.*

| Examination by Dr. Clark's Soap Test. Date of Collection. | Height of gathering Point above low water in Ohio river. | Degrees of hardness by Dr. Clark's Soap Test. P'r Imp. gal | P'r U. S. gal | WHENCE OBTAINED. | Condition of Stream. | Dr. E. S. Wayne's Examinations. Carb. Lime per U. S. gal. | Solid Content per U. S. gal. | Date of Collection. |
|---|---|---|---|---|---|---|---|---|
| May 25 | | 5.75 | 4.79 | Ohio river water, from hydrant in city, | Muddy, 23 feet, | 3.293 | 4.934 | May 14. |
| | | 5.60 | 4.67 | Same water after being boiled, | | | | |
| " 24, | | 5.80 | 4.83 | Ohio river water from river at California | River high, | 4.654 | 6.172 | " 20. |
| June 15, | | 6.10 | 5.08 | " " " " " " " | " low, | | | |
| April, | | 5.66 | 4.72 | Same taken from cisterns in Walnut street, collected in April, 1865. | | | | |
| June 15. | | 6.24 | 5.20 | Ohio river water from river at Pendleton | | 3.670 | 5.200 | June 15. |
| " 15, | | 6.90 | 5.83 | " " " " " Waterworks, | River low, 12 ft. 2 in. | | | |
| " 22, | | 10.10 | 8.42 | Crescent pond, Elmont, north part of city | | | | |
| | 220 | | | Gregory's creek, running in Gr't Miami, | | 8.691 | 11.424 | " 8. |
| May 19, | 280 | 8.85 | 7.38 | Clear creek, in flood, | Day after heavy rain, | 7.142 | 9.566 | " 19. |
| " 30, | 290 | 18.25 | 15.21 | Largest Branch of Clear creek, | Creek low, | 13.279 | 14.812 | " 30. |
| | | 16.50 | 13.33 | " " after boiling, | | | | |
| " 19, | 240 | 15.00 | 12.50 | Great Miami river at Franklin, | River rather high, | 6.723 | 8.947 | " 19. |
| " 18, | 196 | 11.00 | 9.17 | West Branch of Millcreek, | In flood, | 6.215 | 8.02 | " 18. |
| " 20, | 220 | 13.62 | 11.35 | Turtle creek, running into Little Miami, | " " | 8.371 | 11.106 | " 17. |
| " 20, | 222 | 11.80 | 9.83 | Muddy creek, | " " | 5.347 | 8.02 | " 16. |
| June 1, | 50 | 9.25 | 7.71 | Little Miami at Union Bridge, | River high, | 5.275 | 7.096 | " 20. |
| " 15. | | 16.50 | 13.75 | Little Miami at Newtown, | " low, | | | |
| | | | | OTHER WATERS FOR COMPARISON. | | | | |
| May 24, | | 1.33 | 1.11 | Rain water collected at E. 4th st. Cin'ti, | | | | |
| June 8, | | 2.25 | 1.88 | Brooklyn water, Ridgewood Reservoir, | | | | |
| " 6, | | 3.80 | 2.17 | Croton water, from New York City, | | | | |

The great increase of hardness at low water, as compared with the water of the streams when in flood will be noticed in the Little Miami specimens, as well as in those of Clear creek. The Ohio river water is also well marked in this respect, and its greater hardness when low is apparently due to the greatly increased hardness then of the water of the Little Miami river, and similarly of the other streams above, which enter it from the limestone districts.

Professor Locke's minute analysis is not of a nature easily comparable with the ruder measure of the soap test, but if I take the amount of lime in the different waters examined by him, as a basis of comparison, the ratios, taking that given for the Ohio river water as unity, agree very closely with the soap test observations.

The comparison gives the following results:

| WATER—WHENCE OBTAINED. | RELATIVE PROPORTION OF LIME IN THE WATER. | |
|---|---|---|
| | According to Prof. Locke | According to Dr. Clark. |
| Ohio river, twelve miles below Big Sandy, | 0.44 | |
| Ohio river at Cincinnati, | 1.00 | 1.00 |
| Little Miami river | 1.65 | 1.68 |
| Great Miami below junction with Mad river, | 2.57 | 2.63 |
| Mad river | 3.93 | |

In the scale given by Dr. Clark of degrees of hardness corresponding to his soap test, each degree is considered by him equivalent to one grain of carbonate of lime, per Imperial gallon. In the above table in which the United States standard gallon is used by Dr. Wayne, the scale has been reduced to the United States gallon.

Professor Locke's analysis of a specimen of the Ohio river water taken twelve miles below Big Sandy, shows the character of the water before it enters the limestone basin. Here, the water corresponds in softness very nearly with that of the Croton or Cochituate or Brooklyn water; at Cincinnati it has lost a portion of the softness which characterizes it at Big Sandy.

At five degrees of Dr. Clark's scale, water is supposed to be approaching the line of hardness which makes it perceptible, and objectionable for domestic use. The water of the Ohio river borders closely upon this line. To select a water positively objectionable as regards hardness, would, in my opinion, be a great mistake, involving necessarily much dissatisfaction and many inconveniences. But all the waters of the back country which have been examined, are, as the table shows, much harder than the Ohio water. They are, therefore, as compared with the water of the Ohio river, to be decidedly set aside, unless the Ohio river water possesses other qualities more objectionable than the excess of hardness referred to, from which those others shall be found to be exempt. Lime, in all its forms, is conceded to diminish the solvent power of water. Beyond certain limits, its presence makes the water objectionable for family use, whether for drinking, cooking or washing purposes. There is so much evidence extant on these points as to render any labored discussion unnecessary. The limits referred to are exceeded by all the waters examined north of Cincinnati, except that of the Ohio river. For manufacturing purposes, and for steam boilers, hard water is very objectionable; a soft water for all such purposes is always desirable.

One of the most interesting streams which we have examined is "Clear creek," entering the Great Miami river near Franklin. The waters of this creek when not affected by heavy rains, are comparatively clear. Its upper branches are largely fed by springs issuing from limestone rocks. Its banks are generally steep. The water of this creek on the day after a heavy rain, when it was unusually high and turbid, showed seven and a third degrees of hardness as compared with the

Ohio water, which may be taken at four and three-quarters, (per U. S. gallon.) Ten days afterwards, when the stream was about its usual depth for the season, and running clear, its principal branch had changed to fifteen degrees of hardness. In the former case, the rains running off the steep slopes, modified its natural character; in the latter case, the large springs which pour out from the limestone rocks, determined its character. If the waters of the stream were impounded, the measure of hardness would be between these extremes, and could not be assumed at less than ten degrees, while it would probably exceed this estimate.

The waters of the other creeks mentioned in the table, were examined only when in flood. They would have shown higher rates of hardness, had they been examined also when low.

The Ohio river water has the advantage then, decidedly, as regards softness.

As regards organic impurities, the waters of small upland streams are preferable as being generally associated with a sparse population, and consequently exposed in a less degree to the contaminating influences of human life, the populations being always most dense on the borders of navigable rivers.

It is to be remembered, however, that these upland creeks are not in this instance mountain brooks. They all rise and flow through rich agricultural districts, destined to produce heavy crops, and doubtless to be richly manured toward that end. The rain waters falling upon such lands, will be least pure as regards organic matters, when they flow off rapidly, and most pure when they have passed through the soils and rocks, and been subjected to their infiltration.

The sewerage impurities of a large city when delivered into such a river as the Ohio, will always render its waters at, and immediately below the mouths of these sewers, offensive to our instincts of cleanliness and purity, and although the waters of a large river very soon purify themselves from such contamina-

tions, so that their influence could hardly be traced in the water a few miles down the stream, yet such a feeling in the community is to be respected and encouraged as conservative of health.

The point at which the water is taken now for the city use, is objectionable in this respect, as being within the limits of the city, and within the influence of its sewerage discharges. The discharges from Deer creek, which are at certain seasons very offensive, float up stream in the eddy which prevails there, as far as the pumping house. The pipe of the new engine, which is laid well into the current, will be beyond the influence of the Deer creek discharge, but it is disagreeable to have offensive deliveries of this kind approaching that degree of nearness to the portion of the river whence the city derives its supply, and no position for the new works can be satisfactory, in my opinion, which is not clearly beyond any such influence, and beyond the influence of the city sewerage, having in view the growth of the city.

A sensitiveness on this point, not to be satisfied by chemical explanations of the inappreciable effect of such influences on the waters of a large river, it is safer to encourage than suppress.

If the city, then, should continue to use the water of the Ohio river, the water should be taken from some point above the city limits, and the supply pipes carried out well into the channel way. The Ohio river water thus taken, I should consider sufficiently pure at all seasons for city use, and decidedly preferable on the whole, to the waters of the streams examined by us.

The large engine now building, will satisfy the wants of the city until you are prepared with new works, and as the city above the present works is not densely occupied, the water delivered by the new engine, drawn from about mid-stream, will not probably be sensibly affected within that time by the impurities to which reference has been made.

The impurities from the slaughter houses, as well as all similar animal impurities, should not be allowed to enter the river under any circumstances, and the time will undoubtedly come, when the law will protect all streams from the influence of such pollutions, by requiring all such nuisances, at some cost, to be converted into manure, or otherwise rendered incapable of deteriorating the exposed waters, upon whose salubrity all animal life is more or less dependent.

There remains to be considered the turbid character at certain seasons of all the rivers and streams examined by us, and how this turbidity can be removed.

This muddy or turbid character of the streams, obtains during, and for some time after, heavy rains. When any one of these rivers is in flood, it is heavily charged with sedimentary matter: when the river is very low, the water becomes clear, or nearly so.

The Great and Little Miami rivers flow through rich bottom lands, and their waters, when in flood, appear to be more heavily charged with sediment than the waters of the Ohio river. The waters of the smaller streams entering them, are about equally turbid when in flood, but they fall and clear themselves more rapidly than the large streams. This turbidness must be got rid of before the water can be expected to be used freely and liberally by the citizens, not merely for the necessary purposes of the family, but for the luxuries of the bath, etc., so conducive to health and cleanliness.

My stay here since the last of March, has enabled me to watch the state of the water as received in the dwelling houses, through the months of April, May and June. In April and May, when the falls of rain were frequent and heavy, the water was so turbid as to be disagreeable to wash in; no one could be expected to bathe in such water as a measure of cleanliness, though one might possibly do so for the refreshment which its coolness might produce. To use such water freely,

may be said to be unnatural; that it is not used freely, is apparent from the daily consumption of water in the cities of Cincinnati, and of Louisville and St. Louis. As compared with the population the consumption is evidently much below the rates of consumption prevalent in eastern cities, except at times in mid-summer when the water in the river is low and comparatively clear. The consumption, then, increases in a much greater ratio than the change of temperature would warrant.

Until the water can be delivered to the consumers limpid throughout the year, rendering the use of filters and cisterns unnecessary, it can not be expected to be popular; nor to be used with that freedom bordering on waste, which, in a hot climate, is so conducive, as I have already said, to health and cleanliness.

The income necessary to meet the cost and maintenance of a liberal water supply can hardly be expected to be obtained, until the character of the water at all seasons has been rendered limpid, and desirable both for manufacturing and domestic purposes.

That this result can be secured, I am not at liberty to doubt, because the waters of certain rivers in Europe, discolored under the same circumstances, are cleared satisfactorily by a simple process of filtration through beds of sand and gravel. When the river carries much sediment, settling reservoirs must first be used, where the water becomes freed of the heavier particles held in suspension, before being thrown upon the filtering beds.

There may be said to be three modes of attaining this end:

1st. By subsiding reservoirs of large area, arranged either in a series, or where space is not important, in the form of one very large reservoir, through which the water in its slow passage deposits all the sediment held in solution.

2nd. By subsiding reservoirs and filter beds combined.

3rd. By the filter beds alone.

In the first case, the subsiding reservoirs must be large enough to clarify the water when in its worst condition, without the aid of the filtering process. Large reservoirs of still water are not desirable in our hot climate.

The second case is more economical of space. Filter beds have been resorted to, not because reservoirs of subsidence would not produce the desired effect, but because these filter beds made the process speedier and dispensed with the necessity for subsiding resorvoirs of large size. In this hot climate, it is, besides, not desirable that bodies of water should remain longer than necessary in an entirely quiescent state. The size of the subsiding reservoir will depend upon the character of the water, and on the average daily consumption, conjointly.

The third mode, of using filter beds without subsiding reservoirs, occurs only where the stream, whence the supply is derived, is but slightly discolored by rain, and never carries in suspension much sediment. It is evidently inapplicable to our great western river waters.

If the waters of the upland streams which we have examined, were decided upon as the most desirable sources of supply for the city, impounding reservoirs would have to be constructed on them, one or more on each stream, of sufficient capacity to hold about four months' supply. These reservoirs would operate as subsiding reservoirs when the streams were in flood, but unless the reservoirs were unusually large, the water in heavy floods would flow out of them, more or less turbid, and some means would have to be adopted at such times (probably at the city end of the conduit) to clarify the water.

The reservoir at Washington, which is fifty-five acres in extent, has entirely failed in this respect. The Croton dam reservoir, on the contrary, delivers the water at its lower end, into the conduit, clear of sediment during the heaviest floods, but not unfrequently slightly discolored at such times. This reservoir is, however, from four to five miles in length, and has,

according to Mr. Schramke, four hundred acres of water surface.

The Ohio river is very variable in its character, as regards the amount of sediment which it carries in suspension. For, from two to four months its water is very heavily charged with sediment, the heavier portions of which rapidly deposit themselves in still water. For some months of the year, varying with the season, its waters are clear, or nearly so. During the remaining months, the waters are more or less turbid and discolored. The means adopted for its purification would therefore have to be used intermittently.

Although I have expressed my opinion in favor of the use of the Ohio river water as preferable, all things considered, to any other water available for Cincinnati, it may be expected that I should give such information in regard to the amount of water which can be collected from the small streams of the back country, as our examination has put us in possession of.

There are no gaugings of any of the creeks referred to, to assist us in arriving at any estimate of their flow of water throughout the year. We are therefore driven to infer their capacities in this respect from the extent respectively of their gathering grounds, and the proportion of the rain fall of "low years" which finds its way into their channel beds.

The extent of the gathering grounds we have been able to measure approximately from the county maps. The amount of the rain fall which can with certainty be depended upon as collectable, must be to a certain extent a matter of judgment. It can not have reference to the mean rain fall of a series of years, but must be founded on the measures of the lowest years of rain fall, for the supply of the city must be made certain during the season of low water, as much as during the fuller seasons.

The aggregate amount of water to be provided for in any scheme for the extension of the present works, must be first

considered. It would seem to be unfair for the present generation to make preparations for more than thirty years' service, except in such parts of the works as without much extra cost can be made applicable to a longer period. But it is necessary to have in view the facilities of extension at the end of that period, and the continued usefulness then of the works that may be determined on now.

In the statement below the population of the city is given from the best authorities within my reach. The rate of consumption of water for the different periods is a matter of judgment. My estimates for the future consumption of water are founded on the supposition of the water being delivered clear and wholesome. If continued to be delivered as now, that consumption would not probably much exceed half these estimates.

In New York and Boston a great deal of water is used by the shipping, which goes to swell the apparent average per head. In this city, however, the shipping, as a matter of convenience, will probably long continue to use the river water. The average daily consumption here, per head, should not therefore be so much as at New York or Boston, except as that consumption may be influenced by the needs of a hotter climate, and by a policy of supply more liberal than that of the cities mentioned. The needless waste of such a blessing as good water, must be deprecated; but, on the other hand, the inculcation of a niggardly use of it is still more objectionable. That freedom in the use of the water which is desirable in the interest of both health and comfort, must necessarily involve a certain amount of waste.

Your resolutions, at the beginning of this report, keep this liberal policy in view as a measure of safety.

The cleanliness of the sewerage drains of the city is dependant on a rather free use of the water, and it is better that the necessary water to that end should reach them after having

been used by the inhabitants, than that it should be flushed into them from the street hydrants, a measure indispensable under certain circumstances, but of less frequent necessity as the contributions from the dwelling houses increase.

## TABLE

*Explanatory of Population of Cincinnati, and of the relative consumption of Water.*

| YEAR. | Gross Population. | Rate of Increase. Per cent. | Average daily Consumption. Gallons. | Estimated number of Inhabitants using Water. | Supposed rate per head per diem. Gallons. |
|---|---|---|---|---|---|
| 1819 | 10,283 | ............ | ............ | ............ | ............ |
| 1826 | 16,230 | ............ | ............ | ............ | ............ |
| 1840 | 46,338 | ............ | ............ | ............ | ............ |
| 1850 | 115,143 | ............ | 2,240,000 | ............ | ............ |
| 1860 | 161,044 | 39 5-10 | 4,999,393 | ............ | 30 to 40 |
| 1865 | 193,252 | 20 | 5,700,000 | ............ | 30 to 40 |
| 1870 | 225,460 | 18 | 12,100,000 | 220,000 | 55 |
| 1880 | 315,460 | 40 | 18,900,000 | 315,000 | 60 |
| 1890 | 431,644 | 40 | 28,015,000 | 431,000 | 65 |

The daily consumption in New York in 1864, averaged 52.6 millions with a population exceeding 800,000. The daily consumption in Brooklyn in 1864 averaged 8,285,000 gallons with a population somewhat exceeding 200,000. The rate of consumption per head per diem will gradually increase up to a certain limit dependent on the facilities afforded, and the habits and comforts of the citizens. I have not thought it necessary to carry this limit much beyond the measure which prevails in the city of New York now.

The consumption for the year 1890 by this table is supposed to have attained a rate of 28,000,000 U. S. gallons daily; say

30,000,000 as the first measure of any gravitation scheme of supply.

The extent of gathering ground competent to furnish this supply, will now be considered.

The amount of the annual rain fall which reaches the streams varies with the geological character of the particular region. In granite districts, particularly within their mountain slopes, it reaches sometimes to two-thirds and more of the annual amount, while, in the limestone districts, and in flat districts of country, it falls to one-third, and sometimes less. The difference, or remainder, is lost by evaporation, and that sort of absorption near the surface which does not penetrate to the rocks, but goes to the nourishment of trees and plants. As respects elevation, the low water of the Ohio river at Cincinnati is stated to be four hundred and thirty-two (432) feet above tide-water at Albany, and one hundred and thirty-three (133) feet below the level of Lake Erie. The gathering ground which we have in view would be situated 630 feet and upwards above the same tide-water base.

Limestone districts of country are well known to be unusually absorbent of water. The channels of the brooks within the limestone basin become frequently entirely dry in summer. The limestone rocks are very pervious to water, and much of the rain which they receive, instead of escaping again (most of it) as in the other formations, into the neighboring valleys, sinks deep into this porous formation, until it reaches a material which is comparatively impervious, and where the water is held and forced to the surface in copious springs. Sometimes a stratum of limestone of a closer character produces this result, as seems to be the case with the water of Clear creek, whose upper branches are fed by copious springs issuing from the limestone rocks. More frequently this effect is not produced until the waters absorbed reach another character of rock. In this case, the streams within the higher portions of the limestone district will become, in summer, dry, or very low, as al-

ready mentioned, while toward the lowest points of the same region they will become the more abundantly replenished from the issuings of the stored water, unless, indeed, the water should find no opportunity of escaping until below the high water lines of the neighboring coast or valley.

I mention these characteristics of many limestone regions as motives to a cautious estimate of the portion of the rain-fall which could be impounded in reservoirs within such districts. Mr. Homershaw's extensive and minute observations of some of the chalk districts of England, comparing these with the clay districts, showed very distinctly that the streams in the chalk were of smaller size for the same extent of drainage than in the other districts. In other words, that more of the rain-fall was absorbed by the limestone formation than in the other case, and not returned to the river within the district of country observed. In all probability the agricultural character of the chalk district was more productive than the other, and a larger proportion of the rain fall was consumed by the rich vegetation of its surface soil.

In various parts of England, the water flowing off from gathering grounds of known extent, has been carefully gauged *throughout the year*, and compared with the registered rain-fall of the same grounds, but none of these examinations have been made, so far as known to me, upon a limestone district; though the summer discharges of various limestone streams have been carefully gauged, giving, however, the average summer discharge, (a very loose quantity,) and not the minimum summer discharge of these streams.

Experiments made on the high ground of Yorkshire, England, show that sixty-six per cent. of the rain-fall can be impounded there; at Sheffield, forty-two per cent. can be impounded; in Suffolk, thirty-five per cent.; in Lincolnshire, thirty-three per cent.; and at Paisley, Scotland, sixty-seven per cent.

Mr. Hawksley experimented on two hundred square miles, and ascertained that forty-three per cent. of the rain-fall could be collected in reservoirs; but the character of the rocks of the ground experimented on is not mentioned.

In this country some careful experiments were made in the State of New York in connection with the canal reservoirs, the details of which I have no means of giving. The results are stated to be as follows: On the water shed of Eaton brook, (6,800 acres,) with a steep slope and compact soil resting on greywacke rock, elevated 1,350 feet above the sea, sixty-six per cent. of the whole rain-fall was found to flow off. The rain flowing from the water shed of Madison brook, (6,000 acres area and 1,200 feet above the sea,) was found to be equal to fifty per cent. of the annual rain-fall of that district.

It is well known that while a large percentage of the rain-fall of the winter months reaches the streams, a very small percentage of the rain-fall of the summer months finds its way there. We shall arrive then at a closer knowledge of the probable amount of water which can be impounded from any specific gathering grounds, if we divide the year into quarters, and take a varying percentage of the rain-fall of each quarter as finding its way to the channels of the streams. Two years of rain-fall may occur in which the registered amount is forty inches for each, but if twenty inches of the amount has fallen in the one case during the winter months, and but ten inches during the same months in the other case, the amount to be relied upon will be much greater for the first case than for the second.

In the absence of positive data, such as can only be acquired by a careful measurement of one of the Miami's for several years, compared with correct observations of the rain-fall upon the same ground, I will assume, for each quarter, the rates which follow, instead of using a fraction of the aggregate for the year.

The principle which I follow in this respect is obviously right. The proportions assumed for the different seasons will differ with the climate, and the geological character of the district.

We know that during the months of August, September, and October, the streams become very low, and yet during this period the mean rain-fall does not differ sensibly, in this locality, from that of the months of January, February, and March.

During the last mentioned months, the portion of the rain-fall which is evaporated and absorbed is comparatively small. The temperature is low, the strata receptive of water are full, the ground when not frozen is moist, and seventy per cent. of the rain-fall may be safely assumed to be flowing off. In a mountain country, and upon a different geological formation, the proportion would be greater.

In April, May, and June, the condition of things has changed, the ground has been plowed up and sown, vegetation is in active progress, and a high temperature occasionally prevails. The springs are still full, but a large portion of any rain-fall is evaporated, and a large portion absorbed by the roots of grasses, plants, and trees. I assume fifty per cent. of the rain of this quarter to find its way to the streams. In heavy, extended rains it will exceed this proportion, and in high rains it will be much below it. It must be kept in view that the seasons of low rain-fall control an engineer in any estimate of this kind, since the supply for a great city must be placed beyond the risk of low exceptional seasons. If there has been much snow during the first quarter, its melting will extend into April, and will thus augment sensibly the delivery of the streams, in the second quarter, above what would be due to its rain-fall.

In the third quarter, July, August, and September, the average rain-fall has not much decreased, and yet the streams, wells and springs have become very low, the temperature and the

evaporation are at their maximum, the ground is dry and very absorbent, and many of the small brooks in this limestone region will be found dried up. I assume but fifteen per cent. of the rain-fall to reach the streams during this quarter.

In the fourth quarter, October, November, and December, the streams continue low. These are exceptional months, very variable in their character. The temperature in this region of country must be still high through October, but it will begin to change irregularly through November and December. The evaporation will become much reduced, but the springs and water-bearing strata having become more or less exhausted during the previous quarter are now filling up. The ground therefore is storing away a large portion of the rain-fall. I estimate the amount of rain flowing off for these three months as averaging thirty-five per cent.

The only tables of rain-fall which I have used in this connection, are those obtained from the records of the Woodward College of Cincinnati. They embrace a period of twenty-nine years, from 1835 to 1864. The details of these tables will be found in the appendix.

In the following table, I have applied the percentages assumed for each quarter as above mentioned, to some of the lowest years, and also to the means of several series of years.

# TABLE

*Showing the rain-fall of certain years, and series of years, at Cincinnati, and the probable amount of that rain-fall which could be collected in impounding reservoirs, within the limestone region of country north of Cincinnati.*

| Authority. | Years. | Total Rain Fall. | | | | | Proportion Flowing Off in Rivers and Brooks. | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | First Quarter. January, February, March. | Second Quarter. April, May, June. | Third Quarter. July, August, Sept'ber. | Fourth Quarter. October, Nov'ber, Dec'ber. | Annual fall in inches. | First Quarter. 70 Per Cent. | Second Quarter. 50 Per Cent. | Third Quarter. 15 Per Cent. | Fourth Quarter. 35 Per Cent | Inches flowing off annually. | Percentage of annual fall flowing off. |
| Ray,............ | 1838 | 4.10 | 20.89 | 6.94 | 7.52 | 39.45 | 2.87 | 10.44 | 1.04 | 2.63 | 16.98 | 43 |
| Ray,............ | 1839 | 10.00 | 8.80 | 6.77 | 4.05 | 29.62 | 7.00 | 4.40 | 1.02 | 1.42 | 13.84 | 47 |
| John Lea,..... | 1851 | 9.84 | 7.20 | 6.23 | 9.22 | 32.49 | 6.89 | 3.60 | 0.94 | 3.07 | 14.50 | 45 |
| Harper,........ | 1856 | 5.00 | 4.195 | 7.661 | 6.01 | 22.866 | 3.50 | 2.10 | 1.15 | 2.10 | 8.88 | 39 |
| Harper,........ | 1857 | 3.275 | 11.34 | 6.170 | 14.10 | 34.885 | 2.29 | 5.67 | 0.92 | 4.94 | 13.81 | 39 |
| Harper,........ | 1860 | 3.395 | 10.545 | 13.45 | 6.655 | 33.81 | 2.38 | 5.27 | 1.98 | 2.33 | 11.96 | 36 |
| Harper,........ | 1862 | 12.939 | 12.64 | 5.420 | 7.780 | 38.78 | 9.06 | 6.32 | 0.81 | 2.72 | 18.91 | 49 |
| Harper,........ | 1864 | 3.740 | 8.20 | 13.30 | 9.26 | 34.50 | 2.62 | 4.10 | 2.00 | 3.24 | 11.96 | 35 |
| Ray,............ | 1835-50,16 y. | 10.53 | 13.61 | 12.51 | 11.34 | 48.02 | 7.37 | 6.80 | 1.87 | 3.97 | 20.01 | 41.7 |
| Ray and Lea, | 1835-55,20 y. | 10.79 | 13.22 | 11.79 | 11.09 | 46.89 | 7.55 | 6.61 | 1.77 | 3.88 | 19.81 | 42.2 |
| Harper.,...... | 1857-64, 8 y. | 7.562 | 11.975 | 10.001 | 9.886 | 39.428 | 5.29 | 5.98 | 1.50 | 3.46 | 16.23 | 41.1 |

The following means of six years of rain-fall (1859–64,) are compared with the mean depths of water in the Ohio river for the corresponding periods, as given by Mr. Shield in his report for 1864:

| YEARS 1859 TO 1864. | First Quarter. January Feb'ary, March. | Second Quarter. April, May, June. | Third Quarter. July, Aug't, Sept'r. | Fourth Quarter. Oct. Nov. Dec. | Annual rain-fall. | Annual am't flowing off. | Percentage of rain-fall flowing off. |
|---|---|---|---|---|---|---|---|
| Mean rain-fall, in inches,.... | 8.730 | 11.020 | 10.336 | 8.560 | 38.645 | ......... | ......... |
| Amount flowing off, inches... | 6.11 | 5.51 | 1.55 | 2.99 | ......... | 16.16 | 41.8 |
| Mean depth in Ohio river, in feet and inches,........ | 28.5 | 19.10 | 7.10 | 14.4 | ......... | ......... | .... ..... |

The lowest year of rain-fall, with the exception of 1856, which is not considered, by Mr. Harper, reliable, was 1839. The rain-falls of the several months of this year, give 29.62 inches for the total of the year.

The annual fall for 1856 is given as being 22.86 inches; but although Mr. Harper discards this year, it is worthy of note that its very low and exceptional rain-fall, is corroborated by the observations made at some other places in the State.

The rain-fall for that year is reported as

At Massillon, ........................................................23.25 inches.
" Granville, Sidney county,........................................24.98 "
" Cleveland, ..........................................................25.63 "
" College Hill, Cincinnati,........................................19.72 "
" Germantown,.......................................................24.15 "

Setting aside 1856, the years which give the lowest amounts for that portion of the rain-fall flowing off, are 1839, 1860, and 1864. The first gives 13.84 inches as flowing off, (47 per cent. of the annual fall;) the second 11.96 inches, (36 per cent. of the annual fall;) the third, also, 11.96 inches, (35 per cent.)

I will take twelve inches as the amount which may be counted on as available for impounding reservoirs during the lowest seasons, and I do not think that for this geological formation it would be safe to assume more. This is equivalent to a discharge of 571,000 gallons per square mile per diem.

The quantity assumed above as requisite for the supply of the city, being thirty millions of gallons per diem, it will be necessary to collect the rain-fall from an area of fifty-two and a-half square miles, at the least.

It must be remembered that to secure an equivalent of twelve inches of the rain-fall, in impounding reservoirs, more than that quantity must be collected, for such reservoirs are not made water-tight, and the loss by infiltration must always be considerable.

In the table above given, it is worthy of note, that during a series of twenty years, the mean rain-fall, per quarter, is a trifle greater in the third and fourth quarters, than in the first or winter quarter, and yet the Ohio river is very low in the third quarter, and also low in the fourth as compared with the first quarter, thus proving the correctness of the assumption made above, regarding the small proportion of the rain-fall reaching the streams during that quarter.

In the valley of the Great Miami, and in the valley of Mill-creek, three small streams have been indicated as possessing gathering grounds, at the elevation requisite for a gravitation supply, sufficiently extensive to warrant the construction of storage reservoirs.

| | | |
|---|---|---|
| The drainage area of Clear creek is.................. | 39.90 | square miles. |
| " " " " Gregory's creek is......... | 16.00 | " " |
| A total of............................................. | 55.90 | |

Giving 4.40 square miles in excess of the 52-50 square miles which we have estimated to be necessary in this district of country to meet a demand of thirty millions of gallons per diem.

This rate of supply could be more than doubled hereafter by taking in, as wanted, the gathering grounds of the West Branch of Millcreek, (28.50 square miles;) Muddy creek, on the Little Miami Valley, (10.25 square miles;) and Turtle creek, on the same valley, (27. square miles.) The water which could be impounded on these creeks, would, it is believed, be less hard than the waters of the great rivers in whose valleys they are situated, but the water at best would be very much harder than that of the Ohio river, as has been already shown.

On the Clear creek valley, the best ground which seems to be available for a storage reservoir, was surveyed, to enable me to make an approximate estimate from that, as a standard of the cost of the requisite number of storage reservoirs on these streams. This survey is shown on map "H." * The reservoir was calculated for forty feet in depth of water at its lower end, and has a water surface of three hundred and eighty-four and seven-tenths acres.

Another smaller reservoir would be required on one of the branches of this stream, and a large one on Gregory's creek.

In the neighborhood of the city, at such convenient place as might be found best, a distributing reservoir would be necessary to receive the waters of Clear creek and Gregory's creek from the conduit, and transfer them by pipe mains to the city. The length of conduit would be about forty-nine miles.

I have given up the idea of any calculation of the probable cost of such a gravitation scheme, because, without minute surveys, such an estimate would be largely conjectural. The character of the water available from these creeks did not warrant my making minute surveys, though the necessary levellings to ascertain the tapping points on these streams, whence the specimens of their waters were obtained, have incidentally enabled me to understand the general extent of their gathering grounds, and their sufficiency, in that respect, as above stated.

* Not printed.

The examination of the different waters having shown that that of the Ohio river was the most desirable for your purpose, I propose now to explain the works which seem to me necessary to secure for some time an abundant supply of water, and to render it to the city, at all times, in a condition fit for use.

It may be well to note here the present condition of the existing works.

There are four pumping engines on the works now, in good condition for daily use. All of these are crank and fly wheel engines, and all of their pumps double-acting. Two of these engines are high pressure non-condensing engines, (combined.) The steam cylinder twenty-one inches diameter, and ten feet stroke; and pumps fourteen inches diameter, and ten feet stroke.

The other two engines are condensing engines; the steam cylinder of each forty-five inches diameter, and eight feet stroke; the pumps eight inches diameter, and eight feet stroke.

The new engine, now building, is a condensing engine, without crank and fly wheel, acting directly on the pump, which is situated immediately underneath the steam cylinder; the steam cylinder is of one hundred inches diameter, and twelve feet stroke; the pump is forty-eight inches in diameter, and twelve feet stroke. This last engine, working at half the velocity of the others, will deliver more water than the four existing engines.

The difference between extreme low water of the river and extreme high water, is sixty-two feet, at the works.

The pumps of the present engines work in the water, and cannot be reached for examination or repair, except when the river is low. The pump of the new engine has been placed in a dry well, and its machinery will therefore be accessible for examination under all the variations of water in the river.

The full waters of the reservoir stand one hundred and sixty-eight feet above low water of the river; the pumps, therefore, work against a varying head of from one hundred and sixty-eight to one hundred and six feet.

The reservoir is reported to hold about five million gallons, or somewhat less than one day's consumption at this date. The average daily consumption of water for A. D. 1864 is reported at 5,391,278 gallons. The running time of the pumping engines, for the year, furnishes the data for this estimate.

The population of Cincinnati, this year, is estimated at 193,-000, and the daily consumption is, probably, below five and a-half million gallons.

In Brooklyn, with a population of about 200,000, and new works, the daily consumption of A. D. 1864, had reached an average of 8,285,000 gallons. In New York and Boston, the consumption for a population equal to that of Cincinnati would exceed ten million gallons daily.

I repeat these points of comparison only as indicative of the character of the water here, which at certain seasons is used unwillingly by the inhabitants. During the worst months in the season, when the river is in high flood, the water is so turbid as to be really unfit for use.

As regards pumping power, when the new engine is finished, the city will be very amply provided for many years; the reserve of water, in store, will be very deficient until a new reservoir is built; but if the pumps are maintained in good order, this evil may not be felt.

The use of large brick cisterns prevails at present in the back yards of all good dwelling houses. These are made large enough to hold three to four months' supply, and are filled when the river water is low and clear, unless, as sometimes happens, they are replenished by rain water, which clarifies itself by settlement and by some fermentation. Many of these

cisterns leak, and must make the cellars and walls of the houses damp and unwholesome. Under a system of supply which would furnish clear water, (provided that water were soft,) these cisterns would become superfluous, and would be gradually dispensed with. The cost and maintainance of such cisterns must form a considerable tax upon the householder now.

We have then to consider:

First—The means available for the purification of the Ohio river water when turbid.

Second—The size and position of a sufficient storage reservoir; and,

Third—The character of the pumping power applicable to these, and incidentally its position upon the river bank.

The purification of river water, for city uses, by filtration through beds of sand and gravel, has long been in use in England, and in certain parts of France and Germany.

It is doubtful whether any rivers carrying so much sediment as the Ohio and Mississippi rivers do, at certain seasons of the year, have been subjected to this process, but the basins or reservoirs of deposit, which in such case are preliminary to the process of filtration meet this difficulty. The greater the amount of sediment carried by a river, the longer must be the time given it to deposit the coarser portions of this sediment, before placing the water in the filter bed. The water can always be reduced in this way, to a condition which shall make the filtering process successful, and render it, finally, clear and limpid. The process is calculated to get rid of the mechanical impurities of the water, it cannot effect any impurities held there in chemical solution.

I have arranged for three reservoirs of deposit or settling basins, the present capacity of each being twenty-eight million United States gallons—while one basin is being drawn off, another is full of water undergoing deposition of its sediment,

and a third is being filled. Two days are supposed to be occupied in filling, when the consumption equals fourteen million gallons daily; during two days the water remains still and deposits the larger part of its sediment, and during two days thereafter, it is gradually drawn off upon the filter beds.

The capacities of these settling reservoirs can afterward be increased as the city consumption increases, by raising the embankment works five feet; each basin will then hold forty-eight million of gallons; and when the city consumption has reached thirty millions per diem, the time of settlement then, in still water, would be one and a-half days, except as the pumping power then in existence may be sufficient to fill the basins in less than two days, and to increase in this way the time available for settlement in still water.

I am satisfied that the process of deposition of whatever is held in suspension will always take place more rapidly in water which is at rest, than in water which is in motion, however slowly. A certain portion of the sediment would deposit itself under a slow motion, as will be the case here while the basins are each being filled; but a state of perfect rest is, in my opinion, economical, both of the time requisite, and of the extent of basin requisite to bring the turbid water into the condition which fits it for the successful action of the filter beds. At certain seasons of the year, the filter beds would not be required. At such times the water would pass directly from the settling basin to the pump well.

In England the time allowed for settling seems rarely to exceed one day; sometimes but one night. The waters of their rivers, though they may have that opaque and milky hue which so frequently prevails after heavy rain, cannot carry in suspension the amount of earthy matter which obtains, under such circumstances, in our western rivers.

The settling reservoirs are arranged for eighteen feet in depth of water — fifteen feet of which can be drawn off.

The sedimentary deposit would be drawn off into the river by a 20-inch pipe arranged in each reservoir for that purpose. This deposit should not be allowed to accumulate to more than six inches in depth.

The sluice chambers, by means of which the water is drawn off from each of the settling reservoirs, are arranged so that the attendant can graduate the delivery to meet the portion of water and the hight of water proper for the filter beds.

The proposed arrangement, as shown on plan C, contemplates two filter beds. These filter beds must be placed low enough to command the water of the settling reservoir. They admit of having from two to three feet in depth, of water, upon the filtering surface. The water, after passing through the filtering material, passes on to the well of the pumping engine, whence it is pumped up into the storage reservoir.

The filter beds are composed of sand and gravel, (seven feet in depth,) arranged as shown in section on plan C. There are two of them, each 640 feet in length by 200 feet in width. The space of ground reserved toward the river will admit of the construction of a third one hereafter.

The top of the filter bed, for three feet in depth, consists of the finest clean sand which the neighborhood affords. The filter is kept in working condition by removing about one inch of the surface sand every week, or every fortnight, according to the state of the water thrown upon its surface. When from eight to ten inches in depth of this sand has been removed in this way, a corresponding depth of clean sand is restored, to be removed again gradually, as the circumstances require. The sand removed is washed and used over again. At long intervals, to be determined by experience, the whole material of the filter bed would have to be removed and replaced.

In England the filter beds are found to filter at the rate of from 50 to 75 imperial gallons per square foot of surface area per diem, varying in this respect, apparently, with the charac-

ter of the stream. I have assumed them to filter 60 U. S. gallons (equal to 50.14 imperial gallons) per square foot of surface. Their present dimensions, at this rate, give a capacity of filtration of 15,000,000 gallons (U. S.) daily.

The other filter bed will have to be added when a larger consumption requires it. The rate of filtration can, besides, be increased to 75 or 80 gallons per superficial foot by adding to the depth of sand upon the filter beds. But if the settling reservoirs are made to perform their parts efficiently, the depth of material arranged for now, should filter the water clean at the rate of 75 U. S. gallons. I have been guided by the lower rate only as a measure of caution.

The third filtering bed referred to, together with the increased filtering capacity which can be created when needed, will enable the filtering apparatus to meet the estimated consumption up to A. D. 1890, when another series of similar works situated further up stream would have to be provided.

These filter beds, their details and connections with the settling reservoirs, can be best understood by an examination of the proper plans. They should be roofed over to protect the shallow water lying upon them from the direct action of the sun.

I desire to repeat here that the filtering bed is not necessary except as an economizer of time and space. With large reservoirs of deposit, of capacity to admit of the water lying still, under its worst conditions, from ten to twenty days, they would not, probably, be necessary, nor would they under the common form of collecting reservoir, if of 300 to 400 acres water area. I have known the Ohio water to retain a milky hue after having been upward of twenty days in a cistern, but this is very unusual. Such large reservoirs as would be necessary to effect the same end, can not conveniently be obtained in the neighborhood of large cities, nor are they desirable if the more compact combination of settling basin and filtering bed has been found efficient; the settling basin in this last case being of

barely sufficient dimensions to insure the amount of deposition which best fits the water for the action of the filters.

To enable me to judge of the head or pressure of water necessary to operate the filters, I have had two water-tight boxes made, (4 by 4 each and 9 feet deep.) The one was filled with the materials usually composing a filter bed and was prepared with pipes, &c., to control the head. From the other, containing the river water, the flow was graduated so as to meet the rate in gallons per diem per superficial foot of filter surface, which I have elsewhere mentioned as governing the English practice. The head required was found to be $3\frac{3}{4}$ inches for the rate of flow upon which the proposed filter beds at Pendleton are predicated, and 5 inches for the maximum rate of 75 imperial gallons per diem, in practice in England. A greater head would be required as the surface of the filter became clogged with sediment.

The water of the river during these experiments, although much discolored, carried but little palpable sediment in suspension, (20th to 26th June,) and therefore the filtering qualities of the material contained in the box were not as severely tested as was desirable; the indications were, however, satisfactory in this respect. The materials for the filter beds will have to be experimented on as regards their proportional thickness and their gross depth, before specifying its precise character. There having been no application thus far in the United States of this mode of rendering turbid water limpid, on a large scale, I labor under the disadvantage of addressing those who have had no opportunity of personal inspection of such works, and who have not had time, probably, to make them their study.

It will, therefore, not be out of place in me to say here, that, before determining on any such work, it will be very important that one or more of your members should visit England, and perhaps France, both to obtain that confidence in their successful operations which a personal inspection would give, and to take advantage of the latest improvements in a process

of which in England they have now had a very lengthened experience; and while there it would be most important to submit any plans you may be disposed to adopt, to the judgment of some English or French engineer of experience in the construction of filter beds, that any omission or defect in your plans may be corrected or modified. No engineer in the United States, that I am aware of, has had an opportunity of acquiring that practical acquaintance with this special branch of hydraulics which the construction of such works only can give; and while I believe that I understand the principles that govern them, it is hardly possible but that I should overlook some of the details on which their successful working may very much depend.

The water having been drawn from the river and purified, must next be accumulated in a storage reservoir of sufficient capacity to render the city safe under any unusual interruption of its supply power, as well as to admit of all necessary repairs, whether of engines, settling basins or filters, being made safely and carefully, and not hurriedly or inefficiently.

The storage reservoir, arranged as shown on plans B and G, has a capacity of 152,120,000 U. S. gallons. The capacity of the first New York reservoir is 150,000,000 gallons; the Brooklyn reservoir 160,000,000. This will furnish ten days' reserve of water when the daily consumption equals 15,000,000, and five days' reserve when it has reached 30,000,000.

This storage reservoir is located upon a small branch of Crawfish creek, and is situated about 3½ miles northeast of the existing reservoir outside of the city limits, and nearly opposite to the village of Pendleton. Between this point and the present works we have not been able to find any ground upon which a reservoir of sufficient size could be constructed. Equally good or better ground can probably be had higher up stream, or up the valley of Crawfish creek; but the present location is preferred at present as the one most convenient now to the heart of the city. The construction of a storage reservoir in

this little valley will involve some heavy excavations and embankments, but the situation is a very safe one, and in connection with the other works will be very convenient. To economize the work of its construction, it is arranged for 25 feet, in depth, of water. The bottom will be situated 179 feet above low water, which will make its highest water 204 feet above low water. Its ordinary mean hight may be taken at 200, which, if 16 feet be allowed for the head lost by friction in the pipe main to be laid from the new reservoir to the existing pipe main at the old one, would give 11 feet of greater pressure upon the city during the day-time than prevails now. The high water of the existing reservoir stands 172 feet above low water of the Ohio river; the discharging mouths of the existing force mains from the engine house are 174 feet above the same low water.

The reservoir proposed is calculated to be puddled on the bottom as well as on the sides, as shown on plan G, and the drainage water of the neighboring slopes is carried away from it by pipes into the creek below.

The influent chamber of this reservoir, where the water is received from the pumps below, is arranged for three 42-inch force mains. The effluent chamber, where the water is delivered to the city, is also arranged for three 42-inch mains.

A division wall separates a portion of the reservoir from the rest, to admit of either portion being cleaned, examined or repaired. It would have been better to have had the two divisions of about equal capacities, but this advantage could not be attained in this case without much loss of water space, where that space is very costly. The present arrangement, under ordinarily careful management, will substantially answer the same purpose. The water is delivered into the further tongue of the reservoir—that the circulation may be as complete as possible, and that dead water upon any part of it may be avoided—it is, on the contrary, drawn off from the side nearest to the city. A waste pipe at the lower end of the reservoir will permit the

low water to be drawn off into Crawfish creek when the reservoir is undergoing repairs or examination. The irregular shape of the reservoir is due to the shape of the ground to which we have sought to accommodate it as far as practicable. To have given it a more regular shape would have much increased the cost of construction.

I forbear going much into details and dimensions of parts, as these are given on the respective plans, and this report is already becoming lengthy.

An examination of plan B will show that the settling basins and filter beds are not in immediate proximity to the storage reservoir just described.

It was my desire, by having them all situated, if possible, together, to simplify the pumping apparatus, so far as attendance is concerned; but the ground does not admit of this being done conveniently, within a reasonable cost.

As the scheme is now arranged, the settling reservoirs and the filter beds are placed on the river bottom. The pumping engines for delivering the water into the settling basins are placed on the river bank conveniently to the three settling basins, while separate pumping engines placed near the filter beds deliver the clear water, after it has been rendered limpid, into the storage reservoir aforesaid, which is placed high enough to command that part of the city now supplied with water. This arrangement, which has been forced upon us, is, by the nature of the ground, more perfect than would have been the simpler one of carrying the turbid water of the river at once to a hight somewhat above the level of the storage reservoir. All the sediment in that case would have been lifted 200 feet above low water; whereas, it is now lifted but 64 feet above low water. In the other case it would have been returned to the river from that great hight by flushing, or accumulated at some expense in the valley of Crawfish creek. At present its near proximity to the river, both as regards hight and distance, will render its

removal comparatively cheap and easy. I am not able to state the weight of sediment which would thus have had to be raised yearly a superfluous hight of 130 feet, but it would evidently have been considerable.

The pumping engines of the upper lift, raising only clear water under a fixed head, will evidently admit of being kept in order at less expense for the same work than the pumping engines on the river bank lifting the turbid water there under a variable head.

The action of the sediment held in suspension by the river water upon valves and boilers, must be unfavorable. It becomes then desirable in the interest of the machinery, simply to confine the river pumping to the shortest lift possible. The arrangement, as a whole, is more complete now than it would have been with one lift, and more pertinent to the precise requirements of the case.

The settling basins and filter beds, when both are in action, will involve an addition to the prevailing lift of about 16 feet. When the filter beds are not in action the loss will be 15½ feet, and if the water from the river should be entirely clear for a sufficient portion of the year to warrant the arrangement, this last item of fifteen feet can be saved. It is questionable, however, whether a certain amount of settling will not be always desirable.

The extent of ground occupied by the settling reservoir and filter beds, &c., is 45 acres. The extent of ground required for the storage reservoir is 39 acres.

A reference to plan B will render the entire movement of the water easily understood: From the river pumps it is delivered into the settling basins; ultimately, from one of the settling basins it passes by a conduit upon the filter beds; from the filter beds it escapes into the clear water basin, and from this small basin as a pump-well it is forced up by the clear water pumps into the storage reservoir. From the storage reservoir, pipes of 3½ feet in diameter convey it to the city.

The character of the pumping engines and of the wells in which they are situated, will be best understood by an examination of the plans.

The plans which show the masonry simply, of the underground work, will first be adverted to.

The foundation pits for the river engine, shown on plan E, are arranged for three pumping engines. The great difference between extreme low water of the Ohio river and extreme high water, (sixty-two feet,) leads to correspondingly massive and expensive masonry. The pits are prepared for a dry well and a wet well. In the dry well all the machinery of the pumps is placed, and made accessible for repair or correction during any stage of the river. In the wet well the water is received by three pipes from the river; these pipes are provided with sluices where they enter this well, by which the water of the river can be shut off, and the water having been drawn off from the well by a small pump, the sediment accumulating on the bottom can be from time to time removed. Two screens are placed in advance of the suction pipes of each pump, to prevent fish or pieces of floating wood from reaching the pumps. Above the sluice-gates of the river pipes, and upon the river walls, sluice-gates are arranged to draw directly from the stream at high-water if need be, as well as to admit of deposits within the well being withdrawn more easily than if carried to the full hight of the engine house floor. The intervening walls in the dry well, carried up to support the machinery, are made to connect by arches with the main division wall of the pit, to give strength to that wall, and so of the intervening walls of the wet well upon which the copper screens rest and slide. The surface of the coping of these pits, which becomes the water-table of the engine house walls, is situated 64 feet above low water of the river.

In regard to the pumping engines, both for the river lift and for the upper lift, I have been aided by Mr. W. E. Worthen, Mechanical Engineer, of New York city. The diagrams ac-

companying the report, together with the estimates of their probable cost, have been prepared by him.

It may be well for me to say here, that, although our judgment leads us to present these forms of pumping engines as very suitable to the condition of things here, there are other forms, such as the Cornish engine, the Brooklyn engine, the Worthington engine, and others which would perform the same duties successfully. Engineers will differ on these points, and the work required can be efficiently performed with one character of engine about as well as another; provided no glaring defects in principle are permitted, and that the workmanship is thorough and the material massive and good.

For pumping the water of the Ohio river when the river is high and its water dark with the amount of sediment carried in suspension, we believe the Cornish form of plunger pump to be more simple in its action and more easily kept in good order than any other. In the Cornish engine proper, the weight of this plunger must bear a certain relation to the work required. With a varying head, therefore, such as obtains upon the Ohio river, the plunger must be arranged to carry a varying weight. The pressure of steam used in the steam cylinder must also vary. The Cornish engines require two corrections, therefore, for the varying head which from time to time occurs in the river by reason of the frequent changes in the hight of its water. The one at the steam end is easily made; the one at the plunger end involves the trouble of moving weights.

In the diagram of the accompanying engine,* while retaining the simple form of the plunger pump, Mr. Worthen gets rid of the necessity of varying weights by using two plungers, as shown in the diagram. The variation for rise in the river will, under this arrangement, be confined to the pressure of steam within the steam cylinder. The plunger poles are in this case acting like ordinary pistons upon the water by the direct force of the steam, and not indirectly by weight, as in the case

*See plan D.

of the Cornish engine. A fly-wheel and crank are added to increase the efficiency of the engine as regards economy of fuel and safety.

This form of engine is in use now upon the new London sewerage works, where it has been applied to meet the same difficulty of a varying head, to which pumping engines placed upon any of the western rivers are subjected. The engine is made competent to deliver at the rate of 15,000,000 U. S. gallons in 24 hours. The extreme lift would be 62 feet; the mean lift, probably, about 40 feet. The pits are arranged for three engines, and so of the engine house. Two of these would be required in the beginning, although one engine, up to 1874, would, probably, be competent to meet the daily consumption, working through the 24 hours; but a reserve engine must always be on hand to place the supply beyond the risk of ordinary contingencies. Beyond 1874, a third engine would become necessary for the same purpose.

The form and size of the corresponding engine house is shown on the plan. The walls of this house rest on the walls of the well pits already referred to. The dimensions inside would be 60 feet by 54 feet. The boiler house is 60 by 52 feet. For the present a portion of the boiler house would be used as a coal shed.

The position of the engine house upon the river bank is, to some extent, indeterminate, and may vary within the limits of the ground occupied by the settling reservoirs according as a thorough examination of the river channel, hereafter, may prescribe.

The length of the supply pipe from the channel to the wet well of the engine, may vary, for the same reason, from the length estimated. Three of these pipes are believed to be sufficient, of four feet in diameter, each.

The position of the engine house, as now defined on the plan, places it opposite to the upper part of the village of Pendle-

ton, and over three miles above the position of the existing engine house. This situation places it about 2,000 feet above the present eastern Corporation line. The topography of the ground has determined the position of the reservoirs, and these again have determined, approximately, the position of the river engine house, which, other things being equal, can not be too near to its work.

As now located, the length of the force mains from the engine pit to the influent chamber of the settling reservoir will be but 140 feet. The length of the force main from the other engine house will be 900 feet. The engines in this house will draw their water from a portion of the river entirely beyond the influence of any contamination from the drainage of the city.

The foundation pits for the clear water engines are shown on plan F. They will have a depth below the 64 foot line of 32 feet, and are intended to be dry and at all times accessible like the other pits. The well or small pond from which these engines would derive their supply is placed immediately outside of the engine house.

The clear water engines have an unvarying lift of 160 feet; the water, too, having been deprived of its sediment, ceases to be so damaging to the valves and pumping pistons.

The engine for this high service, as will be seen by the diagram, is upon the same general plan as the low service engines. This engine is calculated to deliver at the rate of 15 million U. S. gallons in 24 hours into the storage reservoir.

Two engines would be required at the start, the third being built as soon as possible after the consumption per day had reached 15 million gallons.

The engine house of these engines is also shown on plan F; the interior dimensions would be 60 feet by 56 feet; the boiler house 90 by 52 feet.

The following is Mr. Worthen's description of the proposed pumping engines:

"The low service engine is intended to pump the water from the river into the subsiding reservoir. The great depth of the dry well or pit, necessary on account of the extreme variation of level in the water in the river, affords an opportunity of placing the working beam beneath the steam cylinder, and between it and the pumps, making a very simple form of this class of engine, and giving a chance for a very long stroke (12 feet.) The steam cylinder to be 34 inches interior diameter, with a steam jacket, and well clothed; the valves to be of the poppet form, on lifting rods, and raised by a rock shaft in connection with the crank shaft, with an adjustable cut off adapted to the varying lift of the water."

"The cylinder and steam and exhaust pipes to be the only portions of the machine above the level of the engine house floor; the piston rod to extend down through the bottom of the cylinder and to connect directly with the plunger of the pump beneath; connections to be made from the top of the plunger to a double working beam above; to the opposite end of this working beam another pump plunger is attached working into another pump, both pumps are of the same capacity and are placed on the same level.

The water is introduced into the pumps from a main from the river well, extending lengthways of the pit and on one side of it; the water is delivered into a main, parallel with the induction main and above it, on the opposite side of the pit; the valves are the common double-beat, balance valves, of large diameter and small lift, situated between the pumps, with distinct bonnets, and easily accessible.

"The plungers are weighted to the load of the extreme lift. To equalize the work, define the stroke, give positive motion to valves, and to relieve the attendance, a fly wheel is connected

with the outer extremity of the working beam; the fly wheel to be 20 feet in diameter."

"On the opposite side of the working beam, and midway between the center and extremity, are the connections of the air pump; the air pump to be inverted and double acting, placed above the working beam, to connect with a condenser beneath the steam cylinder; the injection water to be taken from the rising main or subsiding reservoir, and the surplus above the boiler feed to be discharged into the reservoir or river; the load on both sides of the beam to be nicely balanced."

"The high service engine to be adapted to the raising of the water from the filter beds or subsiding reservoirs to the receiving reservoir."

"The steam cylinder to be 60 inches diameter, with a steam jacket, and well clothed."

"The working beam to be above the engine house floor, framed of similar pattern to the Brooklyn engine."

"The piston rod to extend up through the top of the cylinder to connect with the working beam, and down through the bottom of the cylinder to connect with the pump plunger."

"The pumps, plungers and working beam to be of the same form and dimensions as those of the low service engine, except that the metal is made thicker to resist the greater strain co-incident to the high service, and the load on the pump plunger is adjusted to the lift. The air pump and condenser to be also of similar form to those of the low service, but of greater capacity, and the fly wheel of greater weight; the injection to be from the filtered water."

"The boilers for the supply of both engines to be of the drop-flue form, 25 to 30 feet long and 6 feet in diameter, and to carry a working pressure of 50 to 60 pounds, to be placed in line,

parallel to that of the engines on the right of the engine house and with their fronts in such a position that the fireman may be within view of the engineer whilst at his station near the hand wheels of the engine."

The storage reservoir would be connected in the first instance with the mains of the existing reservoir by a pipe of 42 inches diameter. At a velocity of two feet per second, this pipe, if protected from rust, would deliver 12,436,556 U. S. gallons in 24 hours.

The effluent chamber of the reservoir is arranged to admit of a second and third pipe main of the same size, as the increased consumption of the city shall require further accommodation; upon this main a branch would be laid and capped for the present to provide for a connection hereafter with a small pumping engine, pumping into an auxiliary reservoir situated upon Walnut Hills, located so as to supply that higher portion of the city when the population upon that high ground shall have become sufficiently numerous to warrant the expense.

The high, rolling plains of Walnut Hills and Mount Auburn, &c., stand from 400 to 450 feet above low water of the Ohio river.

The proposed works at Pendleton will not effectually command a plane situated more than 170 feet above low water of the Ohio river. The population above this plane and upon the high ground referred to, of Walnut Hills, is at present much scattered and in the aggregate of small amount.

I see no sufficient concentration of population there to warrant the construction of permanent works now, for supplying the high ground with water.

It will be better to wait until that population is sufficiently increased, and until the construction of better roads or railroads shall show where it is likely to concentrate. I have, therefore, made no surveys on these hills with the view of de-

fining the position of a secondary reservoir and estimating its cost. An allowance, however, has been made for such a contingency in the estimates, and for an auxiliary pumping service, founded on the cost of a similar work at Brooklyn.

This auxiliary engine would have to raise the water from 210 to 250 feet to meet the requirements of this high service, but its pumping capacity need not, in the first instance, exceed a rate of two million gallons in 24 hours, delivering into a small reservoir of ten times this capacity, which would give a sufficient margin for repairs to the machine.

A much smaller engine and smaller reservoir than I have estimated for, may, possibly, meet more suitably the first requirements of the inhabitants of this part of the city, or a temporary engine working with a stand pipe and without a reservoir, may sufficiently meet the wants of such portion of the residents there, as may be willing to combine for this purpose. The city could furnish the water at a low rate, but would not, probably, be willing to meet the cost of raising and distributing it until there appears some better prospect than now of remuneration for the outlay.

Approximate estimates are appended, of the river works described in this report. In the present state of prices it would be impossible to make a close estimate. I have endeavored to affix prices which will be likely to be in excess of the actual cost, on the supposition that the price of both labor and materials will continue to fall until they approach the rates which prevailed before the war.

The following are the aggregates of the different pieces of work estimated:

| | | |
|---|---|---|
| No. 1. | Three settling reservoirs | $381,436 02 |
| " 2. | The two filter beds | 514,220 50 |
| " 3. | The storage reservoir | 635,386 50 |
| " 4. | The foundations and house for three river pumping engines | 194,823 80 |
| " 5. | The foundation pits and house for three high service engines | 77,285 75 |
| " 6. | The pumping engines, two low service and two high service | 402,500 00 |
| " 7. | The rising main connecting the engines with the reservoirs, and the river induction pipes | 119,979 50 |
| " 8. | The forty-two inch pipe main connecting the proposed storage reservoir with the main of the existing reservoir | 457,355 00 |
| " 9. | Lands and damages, fencing and passage ways | 105,225 00 |
| " 10. | Auxiliary pumping engine and reservoir for Walnut Hills | 150,000 00 |
| | Total | 3,038,214 07 |

The interest on this amount at seven per cent is $212,675.

The cost of the works to the city, per thousand gallons, for instance, would vary with the rate of consumption.

Under a daily consumption of ten million gallons the cost per thousand gallons would be 5 8-10 cents, while under a daily consumption of twenty million gallons, it would be 2 9-10 cents.

Add to these the cost of management and maintainance, to obtain the actual cost to the consumer.

The interest on the cost of the subsiding and filtering reservoirs, at seven per cent

| | |
|---|---|
| Amounts to | $62,696 00 |
| And to this the annaal cost of attendance and repairs, say | 5,000 00 |
| | $67,696 00 |

This would give for the cost of the subsiding and filtering process nearly 2 cents (1.85) per thousand gallons, under a daily consumption of ten million gallons, and nearly one cent

(0.93) per thousand gallons, under a daily consumption of twenty millions.

The average cost of the filtering process in England agrees with the last mentioned rate.

I am much indebted to Col. A. W. Gilbert and to Mr. R. B. Moore for information and aid, in various ways facilitating my labors. The trustees and officers of the existing water works have also been most courteous in answering any inquiries.

I have also to thank Mr. J. J. R. Croes, Principal Assistant Engineer, in this connection, for his valuable aid on the surveys and details, and Mr. C. D. Ward and Mr. P. K. O'Donnell for their very diligent assistance on the same duties.

The conclusions which my examinations have brought me to, although sufficiently expressed in the report, may here be conveniently summed up as follows:

First.—That an ample supply of water can be obtained from the small streams in the back country without resorting to either of the Miami rivers.

Second.—That the Ohio river water is better water for domestic and manufacturing purposes than that of any of the streams referred to, and therefore preferable for the supply of your city.

Third.—That the Ohio river water can be and should be delivered to the citizens clear and colorless, and that this can be accomplished at an expense, small compared with the advantages to be gained thereby.

Fourth.—That the position of any new works should be determined at some point up stream, entirely beyond the influence of the city drainage.

The following maps and plans accompany this report:

A. Map showing the gathering grounds.
B. General plan of proposed works at Pendleton.
C. Sections of settling reservoirs and filter beds.
D. Diagrams of engines.
E. River, or low service engine house and pump well.
F. High service engine house and pump well.
G. Sections of storage reservoir.
H. Map of Clear creek impounding reservoir. (Not published.)

Respectfully submitted,

JAMES P. KIRKWOOD,

*Civil Engineer.*

CINCINNATI, July 3, 1865.

# APPENDIX

TO THE

# REPORT OF THE ENGINEER

## TABLES.

No. 1. Approximate Estimate of Cost of Works Proposed.

No. 2. Table of Rain-fall from 1835 to 1864.

No. 3. Analysis of Eleven Specimens of Water, by Dr. E. S. Wayne.

No. 4. Analysis of Various Waters, by Professor Locke.

No. 5. Relation of Cubic Foot and U. S. Gallon.

# TABLE NO. 1.

## APPROXIMATE ESTIMTAE

*Of the Cost of the Proposed Works, near Pendleton, for the Supply of the City of Cincinnati with Water.*

### I.—SETTLING RESERVOIRS.—(Three in Number.)

| QUANT. | | PRICES. | COST. |
|---|---|---|---|
| 26 | Acres, grubbing and clearing,...................... | $50 00 | $1,300 00 |
| 132,000 | Cubic yards embankment, laid in six inch layers and rolled,................................ | 30 | 39,600 00 |
| 93.000 | Cubic yards puddle, prepared from gravelly earth and clay, worked in courses,......... | 70 | 65,100 00 |
| 30,000 | Cubic yards excavation put in spoil bank,..... | 25 | 7,500 00 |
| 8,570 | Cubic yards dry slope wall of sandstone, sixteen inches thick,............................. | 4 00 | 34,280 00 |
| 4,285 | Cubic yards slope wall, backing of broken stone or egg-sized gravel, eight inches thick,........................................... | 2 50 | 10,712 50 |
| 13,855 | Cubic yards concrete on bottom, six inches thick,............................................ | 8 00 | 110,840 00 |
| 2,361 | Cubic yards masonry in gate houses and culverts,........................................... | 11 00 | 25,971 00 |
| | Extra for cutting of coping, and around sluice gates and pipes, etc.,.................... | ......... | 3,000 00 |
| | Copper wire screens, ................................ | ......... | 1,080 00 |
| 18 | Sluice gates and gearing,.......................... | ......... | 9,000 00 |
| 500 | Lineal feet forty-eight inch pipe, connecting influent chamber with reservoirs,........... | 25 00 | 12,500 00 |
| 1,000 | Lineal feet twenty inch waste pipe,............ | 8 00 | 8,000 00 |
| 600 | Cubic yards riprap protection of exposed points on outer slopes,.......................... | 3 00 | 1,800 00 |
| | Soiling and seeding of slopes,..................... | ......... | 1,000 00 |
| | Add fifteen per cent. for contingencies and omissions, ........................................ | ......... | 49,752 52 |
| | TOTAL COST,........................... | ............ | $381,436 02 |

## APPROXIMATE ESTIMATE OF COST.—Continued.

### II.—FILTER BEDS.—(Two in Number.)

| Quant. | | Prices. | Cost. |
|---|---|---|---|
| 19 | Acres grubbing and clearing,...................... | $50 00 | $950 00 |
| 43,000 | Cubic yards embankment, laid in six inch layers and rolled,.................................. | 30 | 12,900 00 |
| 14,000 | Cubic yards puddling, prepared from gravelly earth and clay, worked in courses,......... | 70 | 9,800 00 |
| 82,000 | Cubic yards excavation put in spoil bank,..... | 25 | 20,500 00 |
| 8,020 | Cubic yards masonry, in walls and chambers, | 11 00 | 88,220 00 |
| | Extra for cutting on sluices and coping,........ | ......... | 2,500 00 |
| 19,000 | Cubic yards concrete in bottom,.................. | 8 00 | 152,000 00 |
| 66,400 | Cubic yards sand and gravel, screened and washed, for filtering material,............... | 70 | 46,480 00 |
| | Roofing of filter beds,............................... | ......... | 110,000 00 |
| 4 | Metal sluice gates and gearing,.................... | ......... | 1,400 00 |
| 4 | Wooden sluices, ....................... ............ | ......... | 600 00 |
| | Soiling and seeding slopes,.......................... | ......... | 1,800 00 |
| | Add fifteen per cent. for contingencies and omissions,........................................ | ......... | 67,072 50 |
| | Total Cost,.................................. | ........... | $514,222 50 |

## APPROXIMATE ESTIMATE OF COST.—Continued.

### III.—STORAGE RESERVOIR.

| Quant. | | Prices. | Cost. |
|---|---|---|---|
| 30 | Acres grubbing and clearing,...................... | $50 00 | $1,500 00 |
| 63,000 | Cubic yards embankment, laid in six inch layers and rolled,................................ | 35 | 22,050 00 |
| 195,000 | Cubic yards filling in bottom, rolled,............ | 30 | 58,500·00 |
| 104,000 | Cubic yards puddling, prepared from gravelly earth and clay, and worked in courses,... | 70 | 72,300 00 |
| 10,550 | Cubic yards clean gravel on bottom,............ | 60 | 6,330 00 |
| 750 | Cubic yards tunnel excavation,.................... | 5 00 | 3,750 00 |
| 120,000 | Cubic yards rock excavation put in spoil bank,............................................... | 1 50 | 180,000 00 |
| 104,000 | Cubic yards earth excavation put in spoil bank,.............................................. | 25 | 26,000 00 |
| 17,885 | Cubic yards dry slope wall of sandstone, sixteen inches thick,........................... | 5 00 | 89,425 00 |
| 8,942 | Cubic yards slope wall backing of broken stone, or egg-sized gravel, eight inches thick,.............................................. | 2 50 | 22,355 00 |
| 2,700 | Cubic yards masonry, in gate houses and culvert,............................................ | 11 00 | 29,700 00 |
| | Extra for cutting around sluices, and pipes and coping,......................................... | ......... | 3,500 00 |
| 1,900 | Cubic yards masonry in division wall,.......... | 8 00 | 15,200 00 |
| 9 | Metal gates and gearing,.......................... | ......... | 4,500 00 |
| | One forty-eight inch stop cock, and one twenty inch double stop cock,............... | ......... | 1,600 00 |
| | Copper wire screens,................................ | ......... | 1,000 00 |
| 600 | Lineal feet twenty inch waste pipe,............. | 9 00 | 5,400 00 |
| 1,800 | Lineal feet twenty inch pipe for drainage of streams,.............................................. | 9 00 | 16,200 00 |
| | Soiling and seeding slopes, ........................ | ......... | 2,700 00 |
| | Add fifteen per cent. for contingencies and omissions,........................................... | ......... | 82,876 50 |
| | Total Cost,................................ | ............ | $635,386 50 |

## APPROXIMATE ESTIMATE OF COST.—Continued.

### IV.—FOUNDATIONS, PITS, AND HOUSE—For River or Low Service Engine, including Space for Three Engines.

| Quant. | | Prices. | Cost. |
|---|---|---|---|
| 8,776 | Cubic yards coursed rubble masonry, with concrete where necessary in foundations, | $12 00 | $105,312 00 |
| 140 | Cubic yards invert sheeting, | 35 00 | 4,900 00 |
| 110 | Cubic yards coping, | 30 00 | 3,300 00 |
| | Extra for cutting around sluice gates, screen, grooves, and pipes, | ......... | 6,500 00 |
| 7 | Metal sluices, with rods and gearing, | ......... | 5,500 00 |
| 3 | Forty-two inch stop cocks, | ......... | 1,200 00 |
| | Earth work, pumping, and coffer dam of foundations, | ......... | 20,000 00 |
| 6 | Pieces forty-two inch pipe, in walls of wet chamber, | ......... | 3,700 00 |
| | Engine house superstructure, | ......... | 19,000 00 |
| | Add fifteen per cent. for contingencies and omissions, | ......... | 25,411 80 |
| | Total Cost, | ............ | $194,823 80 |

## APPROXIMATE ESTIMATE OF COST.—Continued.

### V.—FOUNDATIONS, PITS, AND HOUSE—For High Service Engine, of Size for Three Engines.

| Quant. | | Prices. | Cost. |
|---|---|---|---|
| 2,688 | Cubic yards coursed rubble masonry, upon concrete foundations, | $10 00 | $26,880 00 |
| 65 | Cubic yards invert sheeting, | 35 00 | 2,275 00 |
| 35 | Cubic yards coping, | 30 00 | 1,050 00 |
| 3 | stop cocks, | ......... | 1,200 00 |
| 3 | Pieces of forty-two inch pipe laid in well, | ......... | 1,800 00 |
| | Excavation and pumping in foundations, | ......... | 6,000 00 |
| | Engine house superstructure, | ......... | 28,000 00 |
| | Add fifteen per cent. for contingencies and omissions, | ......... | 10,080 75 |
| | Total Cost, | ............ | $77,285 75 |

### VI.—PUMPING ENGINES.

| Quant. | | Prices. | Cost. |
|---|---|---|---|
| 2 | Pumping engines for the river or low service, at | $75,000 | $150,000 00 |
| 2 | Pumping Engines for the high service, at | 100,000 | 200,000 00 |
| | Add fifteen per cent. for contingencies and omissions, | ......... | 52,500 00 |
| | Total Cost | ............ | $402,500 00 |

The prices above mentioned are given by Mr. Worthen, after consultation with the Superintendent of the Hartford Machine Works.

## APPROXIMATE ESTIMATE — CONTINUED.

### VII—FORCE MAINS.

| QUANT. | | PRICES. | COST. |
|---|---|---|---|
| | The well supply pipes, also the rising mains connecting the river engines with the settling reservoirs, 140 feet in length each; and those connecting the high service engines with the storage reservoir, 900 feet in length each, viz: | | |
| | 280 feet 42 inch main from river engines; | | |
| | 1,800 " " " from H. S. engines; | | |
| | 2,080 " of pipe castings, at 1½ inches thick, equal to | | |
| 654 | Tons pipe castings | $65 00 | $42,510 00 |
| 2,080 | Lineal feet laying, including hauling | 4 00 | 8,320 00 |
| 2 | Check valves and masonry for same | ............ | 4,000 00 |
| | Check masonry on steep bank | ............ | 2,500 00 |
| | River supply pipe, from river engines to channel, viz: | | |
| | Two 48 inch wrought iron pipes, 450 feet in length each | ............ | 37,000 00 |
| | Laying and securing same | ............ | 10,000 00 |
| | Add 15 per cent. for contingencies and omissions | ............ | 15,649 50 |
| | TOTAL COST | ............ | $119,979 50 |

## APPROXIMATE ESTIMATE — Continued.

### VIII.—SUPPLY MAIN.

| Quant. | | Prices. | Cost. |
|---|---|---|---|
| | 17,600 feet forty-two inch pipe main, to connect the storage reservoir with the existing city pipe mains; thickness $1\frac{1}{3}$ inches. | | |
| 4,900 | Tons pipe castings at | $65 00 | $318,500 00 |
| 17,600 | Feet of laying, including hauling | 3 50 | 61,600 00 |
| | Extra grading and masonry at certain points, say | ........... | 15,000 00 |
| | Two stop-cocks and vaults | ........... | 1,400 00 |
| | Six air-cocks and boxes | ........... | 200 00 |
| | Two blow-offs and masonry | ........... | 1,000 00 |
| | Add 15 per cent. for contingencies and omissions | ........... | 59,655 00 |
| | Total Cost | ........... | $457,355 00 |

## APPROXIMATE ESTIMATE — CONTINUED.

### IX.—LANDS AND DAMAGES, FENCING AND PASSAGE-WAY TO STORAGE RESERVOIR.

| | |
|---|---|
| Land damages, (84 acres,) including some houses and lots, say | $80,000 00 |
| Fencing and gates | 5,500 00 |
| Passage ways | 6,000 00 |
| Add 15 per cent. for contingencies and omissions | 13,725 00 |
| TOTAL COST | $105,225 00 |

### X.—AUXILIARY PUMPING ENGINE AND RESERVOIR,

| | |
|---|---|
| For accommodation of population on Walnut Hills, Mt. Auburn, &c., connected with the 42-inch main; rising main to be 20 inches diameter—allow for this | $150,000 00 |

## APPROXIMATE ESTIMATE OF COST—Concluded.

### GENERAL SUMMARY.

| | | |
|---|---|---|
| I. | Three settling reservoirs | $381,436 02 |
| II. | Two filter beds | 514,222 50 |
| III. | Storage reservoir | 635,386 50 |
| IV. | Low service engine, foundations and houses | 194,823 80 |
| V. | High service engine, foundations and houses | 77,285 75 |
| VI. | Two low service and two high service engines | 402,500 00 |
| VII. | Force mains | 119,979 50 |
| VIII. | Supply main to city | 457,355 00 |
| IX. | Land damages and fencing | 105,225 00 |
| X. | Auxiliary pumping engine and reservoir | 150,000 00 |
| | Aggregate estimated cost | $3,038,214 07 |

# TABLE NO. 2.

*Showing the Amount of Rain-fall at Cincinnati from* 1835 *to* 1864, *as observed at the Woodward College, situated about five hundred and sixty feet above the Sea.*

| AUTHORITY. | YEAR. | JAN. | FEB. | MAR. | APR. | MAY. | JUNE. | JULY. | AUG. | SEP. | OCT. | NOV. | DEC. | Annu'l |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. |
| Charles Cist's Book | 1835 | 3.82 | 1.75 | 1.86 | 3.37 | 7.57 | 7.34 | 2.46 | 6.54 | 3.27 | 4.35 | 6.66 | 3.20 | 52.15 |
| Same | 1836 | 2.97 | 4.34 | 4.18 | 4.54 | 9.01 | 2.14 | 7.42 | 5.54 | 4.77 | 3.71 | 4.41 | 4.36 | 57.39 |
| Same | 1837 | 0.80 | 3.43 | 3.70 | 2.00 | 3.79 | 4.38 | 3.83 | 5.91 | 3.14 | 4.16 | 2.52 | 5.05 | 42.71 |
| Same | 1838 | 1.90 | 1.64 | 0.56 | 4.77 | 8.57 | 7.55 | 2.47 | 3.76 | 0.71 | 3.55 | 3.12 | 0.85 | 39.45 |
| Same | 1839 | 4.56 | 2.75 | 2.69 | 2.38 | 4.46 | 1.96 | 2.97 | 0.56 | 3.24 | 0.13 | 2.20 | 1.72 | 30.62 |
| Same | 1840 | 1.13 | 4.68 | 3.65 | 4.78 | 6.08 | 6.84 | 4.45 | 3.73 | 1.56 | 4.74 | 2.50 | 3.20 | 47.34 |
| Same | 1841 | 5.55 | 0.82 | 2.34 | 4.75 | 2.16 | 1.51 | 5.33 | 2.71 | 2.94 | 2.46 | 4.92 | 5.56 | 41.05 |
| Same | 1842 | 2.75 | 6.09 | 3.02 | 2.97 | 3.04 | 5.67 | 2.35 | 4.22 | 2.95 | 1.90 | 3.76 | 2.57 | 41.29 |
| Same | 1843 | 3.51 | 3.54 | 2.97 | 6.15 | 3.54 | 4.52 | 2.92 | 5.89 | 6.73 | 4.16 | 4.26 | 3.00 | 51.19 |
| Same | 1844 | 3.10 | 1.04 | 4.50 | 3.13 | 7.00 | 6.16 | 3.50 | 3.65 | 1.26 | 4.32 | 3.18 | 1.10 | 43.56 |
| Same | 1845 | 3.03 | 1.66 | 5.46 | 1.08 | 1.89 | 11.50 | 3.06 | 6.88 | 7.51 | 2.03 | 1.68 | 0.60 | 46.38 |
| Same | 1846 | 3.59 | 3.23 | 2.26 | 3.51 | 5.17 | 7.53 | 3.93 | 6.10 | 2.50 | 2.19 | 4.26 | 9.25 | 53.52 |
| Same | 1847 | 4.71 | 4.06 | 5.37 | 2.12 | 4.30 | 7.63 | 8.25 | 3.20 | 3.87 | 9.57 | 3.95 | 8.15 | 65.18 |
| Same | 1848 | 4.58 | 2.81 | 6.72 | 0.55 | 5.13 | 1.86 | 6.95 | 3.90 | 1.53 | 3.62 | 2.60 | 9.43 | 49.68 |
| Same | 1849 | 6.48 | 2.04 | 4.70 | 3.65 | 3.61 | 4.90 | 8.90 | 4.41 | 2.68 | 3.86 | 2.42 | 5.32 | 52.97 |
| Same | 1850 | 5.20 | 6.28 | 6.62 | 4.27 | 1.86 | 5.00 | 6.30 | 7.20 | 2.22 | 1.05 | 2.54 | 6.22 | 54.76 |
| John Lea | 1851 | 0.65 | 6.15 | 3.04 | 1.80 | 3.30 | 2.10 | 3.25 | 2.55 | 0.43 | 2.60 | 3.25 | 3.37 | 32.49 |
| Same | 1852 | 2.03 | 5.20 | 5.16 | 5.80 | 3.15 | 5.25 | 2.05 | 4.35 | 4.15 | 2.75 | 4.57 | 9.89 | 54.35 |
| Same | 1853 | 1.53 | 5.14 | 2.14 | 7.70 | 2.21 | 1.90 | 4.81 | 2.16 | 4.70 | 3.78 | 3.30 | 0.73 | 40.10 |
| Same | 1854 | 4.10 | 5.57 | 8.33 | 2.97 | 7.29 | 4.84 | 2.32 | 3.18 | 2.12 | 3.01 | 3.66 | 3.38 | 50.69 |
| Same | 1855 | 3.71 | 1.58 | 3.66 | 3.05 | 5.24 | 8.10 | 4.35 | 4.52 | 2.98 | 1.31 | 5.22 | 3.28 | 47.00 |
| Geo. Harper, Wood'rd H'h S'l, | 1856 | 1.00 | 2.49 | 1.51 | 0.725 | 1.23 | 2.24 | 3.432 | 0.61 | 3.619 | 1.74 | 2.085 | 2.185 | 22.866 |
| Same | 1857 | 5.35 | 1.98 | 0.760 | 2.725 | 5.530 | 3.085 | 2.50 | 2.92 | 0.750 | 4.92 | 5.36 | 3.82 | 34.885 |
| Same | 1858 | 2.060 | 1.74 | 1.05 | 4.340 | 8.320 | 5.690 | 3.01 | 7.97 | 0.850 | 4.66 | 2.57 | 6.41 | 48.670 |
| Same | 1859 | 2.575 | 5.92 | 4.38 | 7.528 | 2.323 | 3.216 | 1.237 | 3.789 | 2.096 | 1.275 | 4.46 | 3.745 | 42.544 |
| Same | 1860 | 1.425 | 1.56 | 0.41 | 5.315 | 3.68 | 1.550 | 7.965 | 0.915 | 4.335 | 1.275 | 3.53 | 1.85 | 33.810 |
| Same | 1861 | 2.575 | 1.805 | 2.08 | 3.875 | 5.91 | 3.802 | 3.622 | 7.100 | 2.939 | 3.774 | 3.617 | 1.095 | 42.194 |
| Same | 1862 | 4.739 | 2.364 | 5.836 | 6.295 | 3.323 | 3.022 | 3.005 | 1.485 | 0.93 | 0.80 | 3.97 | 3.01 | 38.779 |
| Same | 1863 | 5.550 | 3.050 | 4.37 | 2.130 | 2.84 | 3.110 | 3.210 | 2.994 | 3.10 | 3.85 | 2.05 | 3.80 | 40.054 |
| Same | 1864 | 1.850 | 0.990 | 0.90 | 2.430 | 2.34 | 3.43 | 1.250 | 3.415 | 8.635 | 2.92 | 3.40 | 2.94 | 34.500 |

# TABLE NO. 3.

*Analysis of Eleven Specimens of Water, by Dr. E. S. Wayne, Chemist.*

| Whence Procured. | Date. 1865. | Mark on Specimen. | In U. S. Gallon. Solid Cont's. Grains. | In U. S. Gallon. Carb. Lime. Grains. |
|---|---|---|---|---|
| Ohio river, at Pendleton......... | June 15th, | No. 56, | 5.290 | 3.670 |
| Hydrant in the city........ ...... | May 4th, | No. 2 C, | 4.934 | 3.293 |
| Gregory's creek...................... | " 8th, | No. 1 W, | 11.414 | 8.691 |
| Muddy creek ........................ | " 16th, | No. 2 W, | 8.020 | 5.367 |
| Turtle creek........................... | " 17th, | No. 3 W, | 11.106 | 8.371 |
| West Branch of Millcreek...... | " 18th, | No. 4 W, | 8,020 | 6.215 |
| Great Miami, at Franklin....... | " 19th, | No. 50, | 8.947 | 6.723 |
| Clear creek, in flood............... | " 19th, | No. 51, | 9.566 | 7.142 |
| Little Miami, high................. | " 20th, | No. 3 C, | 7.096 | 5.275 |
| Ohio river, at California......... | " 20th, | No. 4 C, | 6.172 | 4.654 |
| Main Branch Clear creek, low, | " 30th, | No. 54, | 14.812 | 13.279 |

# TABLE NO. 4.

*Extract from the Report of* Professor John Locke, *of 14th June,* 1853, *containing the weight of the substances found in* 5,000 *grains (by measurement) in each specimen of Water.*

| Name. | A. | B. | C. | D. | E. | F. | G. | H. | I. |
|---|---|---|---|---|---|---|---|---|---|
| | Ohio river, 12 miles below Big Sandy; May 7, 1853. | Ohio river at Cincinnati. October 23, 1852. | Little Miami river. | White Water river. | Big Miami, below the junction of Mad river. | Big Miami, above the junction of Mad river. | Mad river. | Spring at the Brewery on Syc. Hill. | Whitewater river. |
| Solid matter | 0.343 | 0.577 | 1.27 | 1.302 | 1.491 | 1.551 | 1.633 | 2.54 | 2.975 |
| Lime | 0.070219 | 0.157260 | 0.259149 | 0.487092 | 0.402739 | 0.538388 | 0.617586 | 1.191948 | 0.492953 |
| Magnesia | 0.022948 | 0.067709 | 0.105977 | 0.118154 | 0.211901 | 0.216788 | 0.207809 | 0.224633 | 0.103956 |
| Potassa | ...... | 0.000580 | 0.033254 | ...... | 0.000386 | 0.000773 | Trace. | ...... | 0.005606 |
| Alumina | ...... | ...... | ...... | ...... | Trace. | ...... | ...... | ...... | Trace. |
| Silica (flint) | 0.520000 | 0.023080 | 0.064770 | 0.018228 | 0.071568 | 0.007755 | 0.006775 | 0.061740 | 0.99662 |
| Nitric and organic acid with soda | 0.093927 | 0.129011 | 0.087409 | 0.130948 | 0.115307 | 0.020282 | 0.005759 | 0.004940 | 0.947973 |
| Phosphate of lime | ...... | ...... | 0.083920 | ...... | ...... | ...... | ...... | ...... | ...... |
| Phosphate of Alumina | ...... | ...... | 0.239770 | ...... | ...... | ...... | ...... | ...... | ...... |
| Manganese | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | 0.062475 |
| Iron | Trace. | Trace. | Trace. | Trace. | ...... | ...... | Trace. | Trace. | Trace. |
| Sulphuric acid | ...... | 0.044683 | 0.040559 | 0.025435 | 0.201076 | 0.074931 | 0.045715 | 0.596010 | 0.037122 |
| Chlorine | 0.051807 | 0.024670 | 0.046132 | 0.003700 | 0.018749 | 0.018995 | 0.018009 | 0.172196 | 0.053534 |
| Carbonic acid | 0.052099 | 0.130007 | 0.309060 | 0.518443 | 0.469274 | 0.673088 | 0.731347 | 0.753298 | ...... |
| Total | 0.343 | 0.577 | 1.27 | 1.302 | 1.491 | 1.551 | 1.633 | 3.004765 | 2.975 |

Analyzed by ........................ J. M. LOCKE.

# TABLE NO. 5.

*Showing the Relation of the U. S. Gallon to the Cubic Foot, and vise versa.*

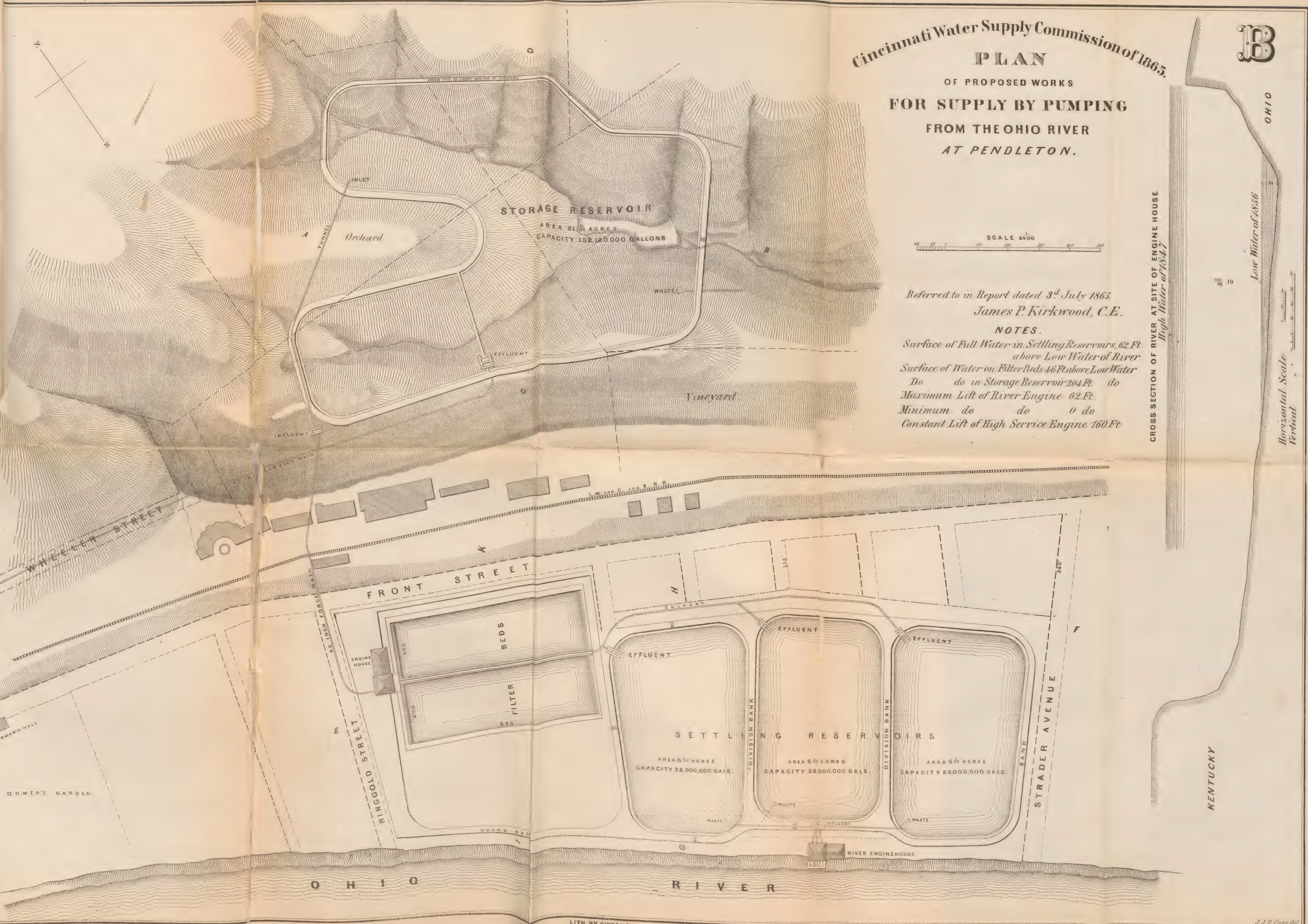
| Cubic Feet. | U. S. Gallons. |
|---|---|
| 1 | 7.4805195 |
| 10 | 74.805195 |
| 100 | 748.05195 |
| 1,000 | 7480.5195 |
| 10,000 | 74805.195 |
| 100,000 | 748051.95 |
| 1,000,000 | 7480519.5 |

| U. S. Gallons. | Cubic Feet. |
|---|---|
| 1 | 0.133680555 |
| 10 | 1.33680555 |
| 100 | 13.3680555 |
| 1,000 | 133.680555 |
| 10,000 | 1336.80555 |
| 100,000 | 13368.0555 |
| 1,000,000 | 133680.555 |

The U. S. Gallon contains 231 cubic inches, and weighs 8.355 pounds.

The Imperial Gallon contains 277.274 cubic inches, and weighs 10 pounds.


SKETCH OF THE DRAINAGE BASINS OF THE GREAT & LITTLE MIAMI RIVERS AND INTERVENING STREAMS.
Showing by color the portions of the gathering grounds of each accessible to Cincinnati under a system of Water Supply by Gravitation June 1865.
Referred to in report of 3rd July 1865. James P. Kirkwood C.E.
A
LOGAN Co.
SHELBY Co.
DARKE COUNTY
CHAMPAIGN Co.
MIAMI Co.
CLARKE Co.
MONTGOMERY Co.
PREBLE COUNTY
GREENE Co.
CLINTON Co.
WARREN Co.
BUTLER COUNTY
HAMILTON COUNTY
CLERMONT Co.
BROWN Co.
HIGHLAND Co.
KENTUCKY
DRAINAGE AREA 2576 sq.M.
DRAINAGE AREA 300 sq.M.
DRAINAGE AREA 39.9 sq.M.
DRAINAGE AREA 27 sq.M.
DRAINAGE AREA 28.5 sq.M.
DR AREA 10.25
16 sq.M.
4.25
4.5 sq.M.
GREAT MIAMI RIVER
Mad River
Little Miami River
OHIO RIVER
Miami Canal
DAYTON
SPRINGFIELD
URBANA
XENIA
TROY
LEBANON
HAMILTON
CINCINNATI
EATON
GREENVILLE
BELLEFONTAINE
WILMINGTON
BATAVIA
REFERENCE TO THE COLORS AND AREAS.
Gathering grounds of Great Miami GREEN 2576 sq.M.
Little Miami NEUTRAL 300
Turtle Creek CARMINE 27
Muddy 10.25
Gregory's BLUE 16
Clear 39.9
Wm B. Mill 28.5

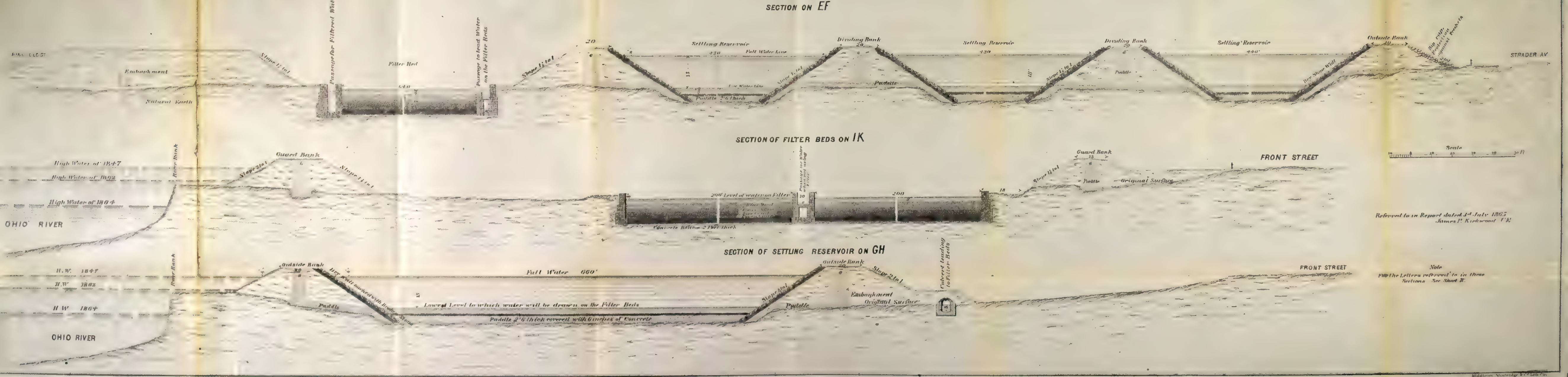


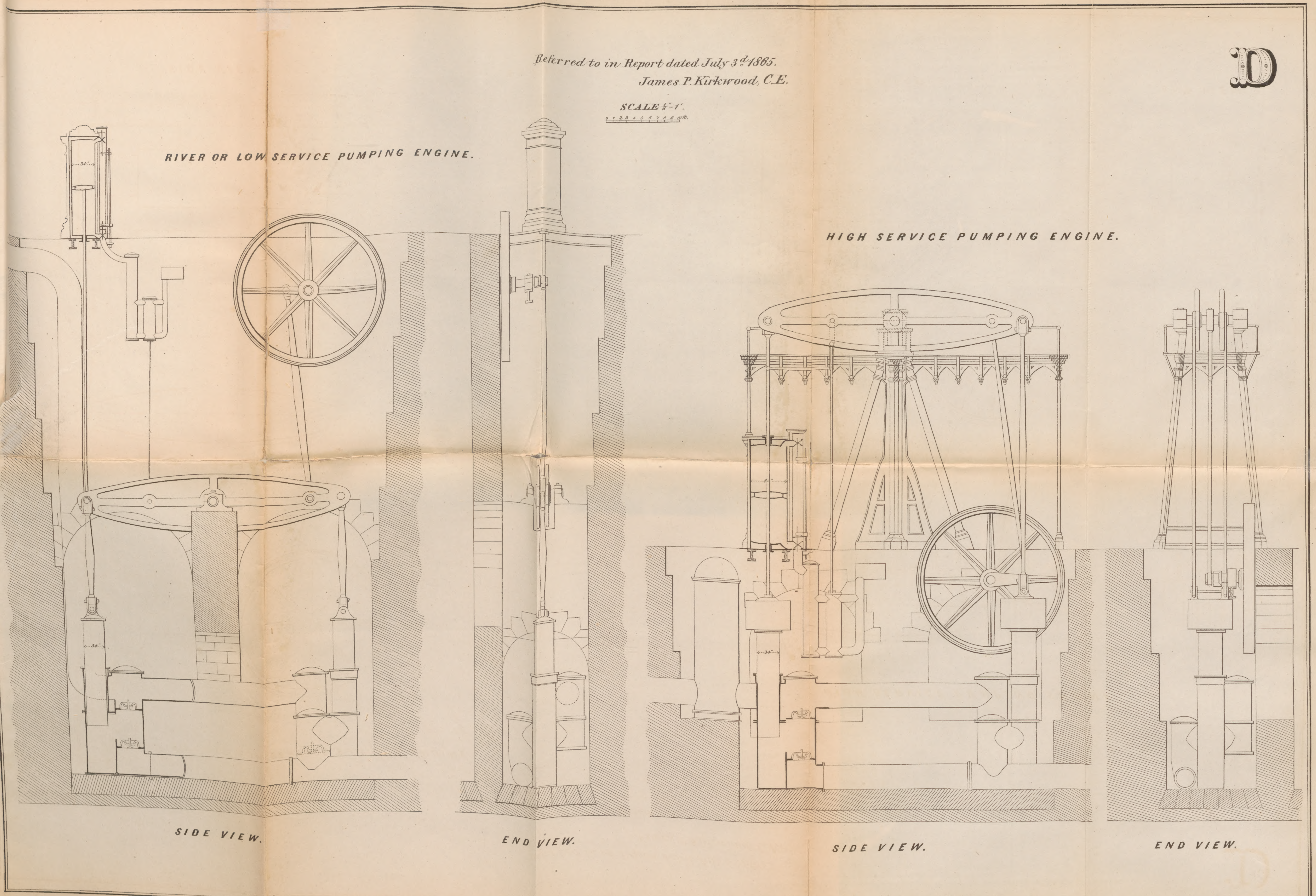

LITH. BY GIBSON & Co. 123 MAIN ST. CIN. O.

J.J.R. Croes del.

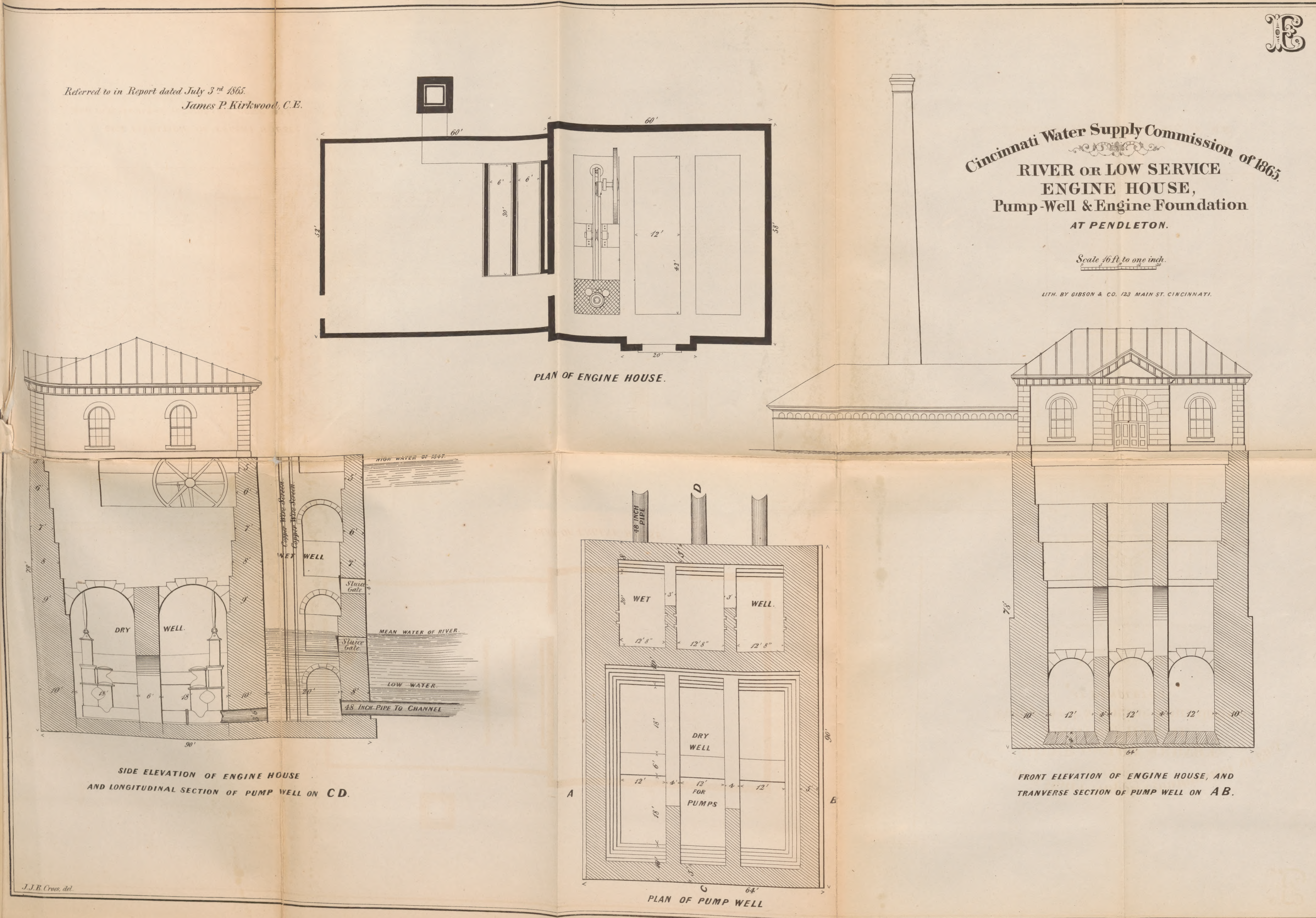
# SETTLING RESERVOIRS AND FILTER BEDS.

E






LITH. BY GIBSON & Co. 123 MAIN ST. CIN. O.


E
Referred to in Report dated July 3rd 1865.
James P. Kirkwood, C.E.
Cincinnati Water Supply Commission of 1865.
RIVER OR LOW SERVICE
ENGINE HOUSE,
Pump-Well & Engine Foundation
AT PENDLETON.
Scale 16 ft. to one inch.
LITH. BY GIBSON & CO. 123 MAIN ST. CINCINNATI.
PLAN OF ENGINE HOUSE.
60'
60'
6'
6'
30'
52'
12'
42'
58'
20'
HIGH WATER OF 1847.
WET WELL
Sluice Gate
DRY
WELL.
MEAN WATER OF RIVER.
Sluice Gate
LOW WATER.
48 INCH PIPE TO CHANNEL
Copper Wire Screen
Copper Wire Screen
78'
90'
SIDE ELEVATION OF ENGINE HOUSE
AND LONGITUDINAL SECTION OF PUMP WELL ON CD.
48 INCH PIPE
D
WET
WELL.
12' 8"
12' 8"
12' 8"
DRY
WELL
FOR
PUMPS
12'
4'
12'
4'
12'
90'
A
B
C
64'
PLAN OF PUMP WELL
78'
10'
12'
4'
12'
4'
12'
10'
64'
FRONT ELEVATION OF ENGINE HOUSE, AND
TRANVERSE SECTION OF PUMP WELL ON AB.
J. J. R. Croes, del.

# Cincinnati Water Supply Commission of 1865.

# F

## HIGH SERVICE ENGINE HOUSE,

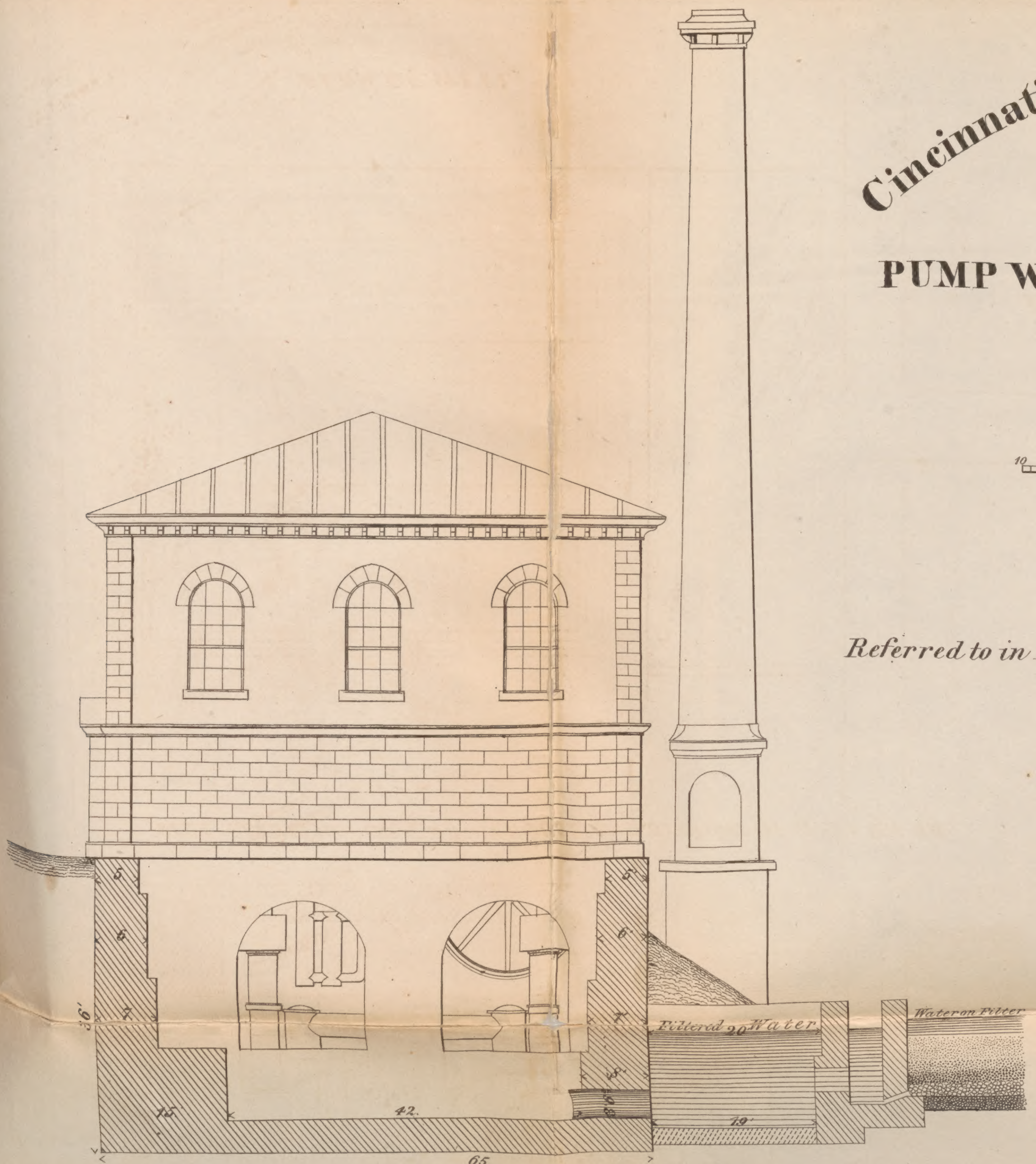
## PUMP WELL & ENGINE FOUNDATIONS

## AT PENDLETON.

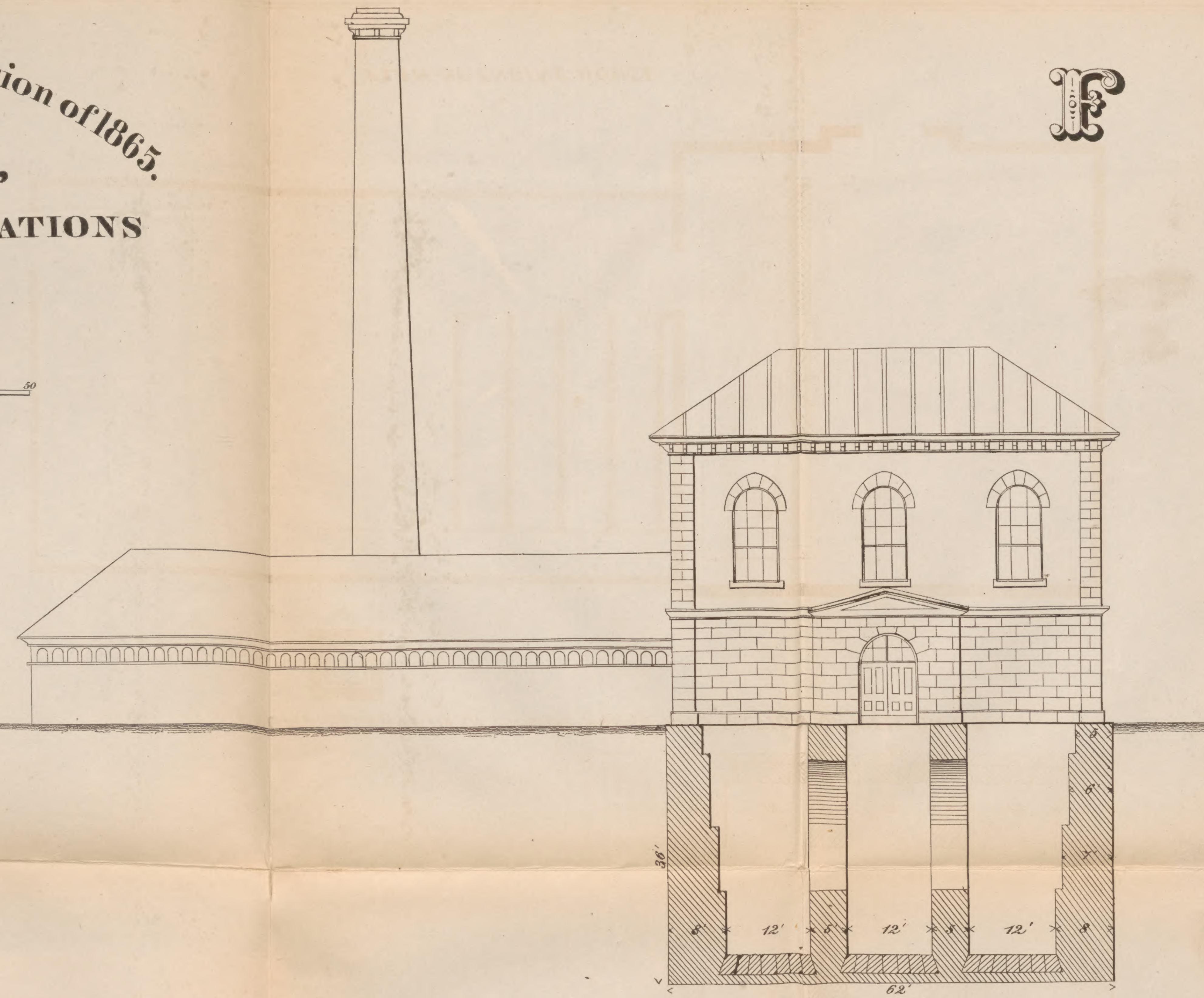
SCALE.

10 0 10 20 30 40 50

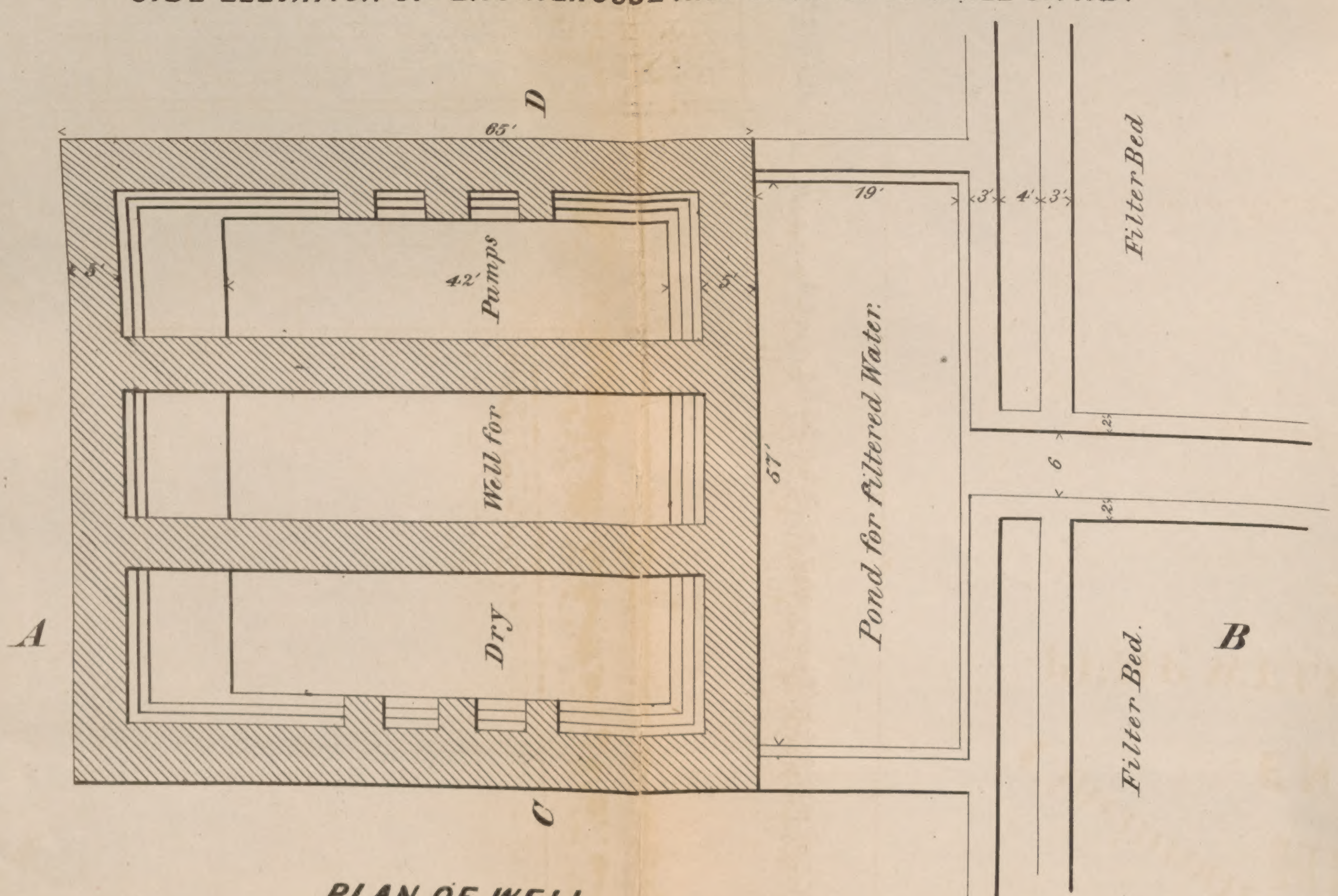
*Referred to in Report dated 3.d July 1865.*
*James P. Kirkwood, C. E.*



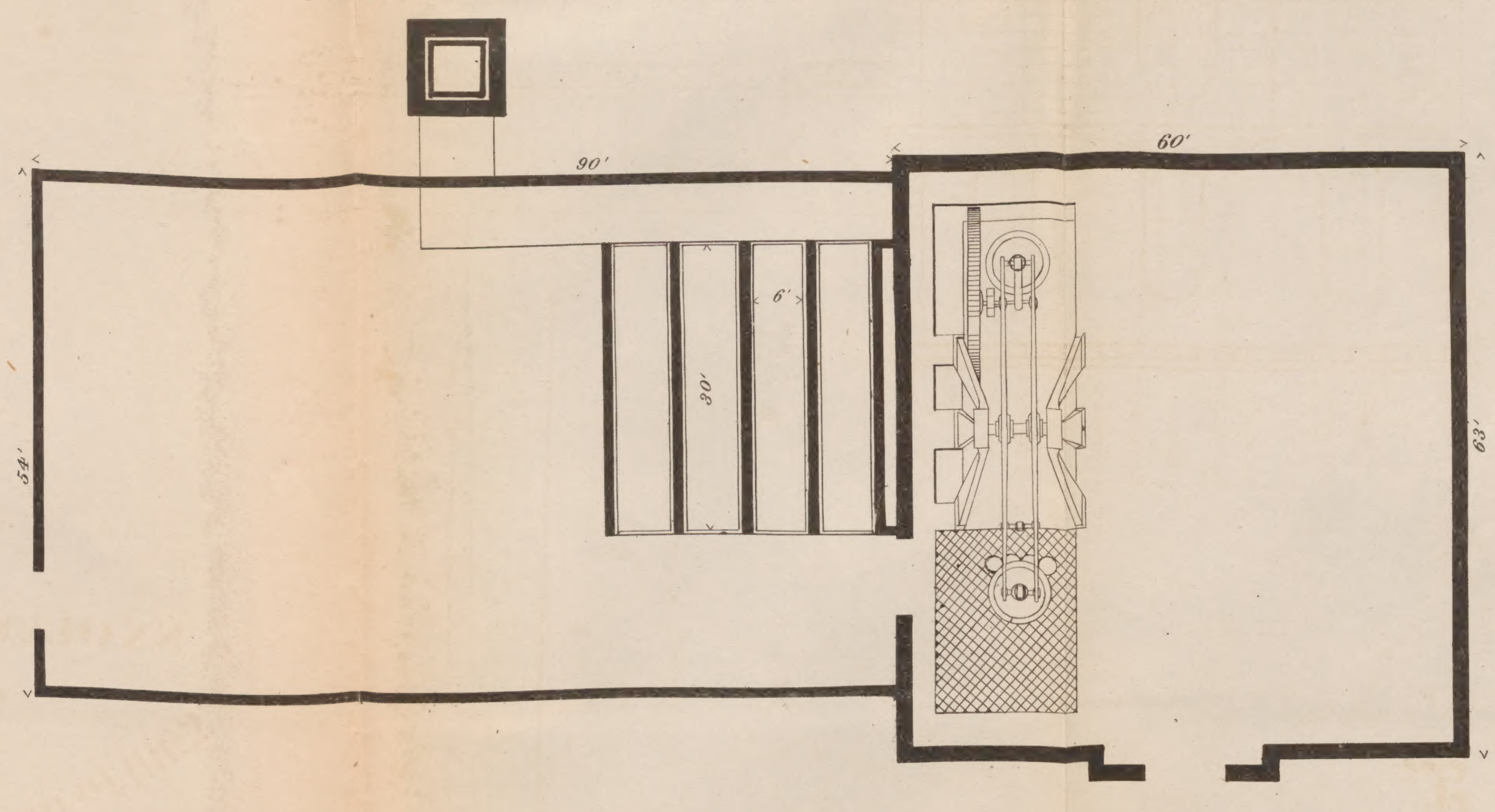

SIDE ELEVATION OF ENGINEHOUSE AND SECTION OF WELL ON AB.




FRONT ELEVATION OF ENGINE HOUSE AND SECTION OF WELL ON CD.

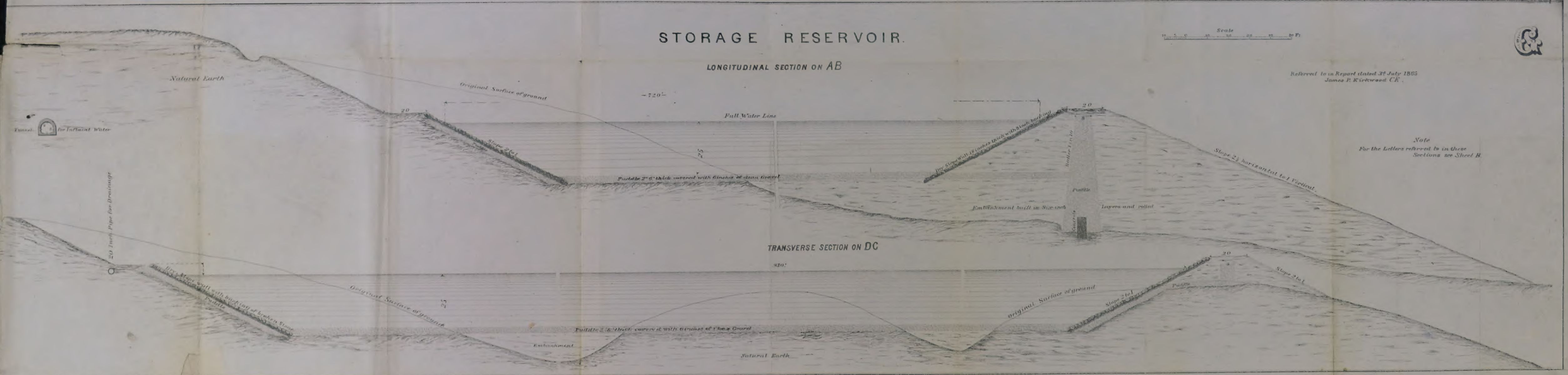



PLAN OF WELL.




PLAN OF ENGINE HOUSE.

LITH. BY GIBSON & Co 123 MAIN ST. CIN.


STORAGE RESERVOIR.
LONGITUDINAL SECTION ON AB
Scale
Referred to in Report dated 3d July 1865
James P. Kirkwood C.E.
Natural Earth
Tunnel for Influent Water
Original Surface of ground
720
20
Full Water Line
Slope 2 to 1
25
Puddle 2' 6" thick covered with 6 inches of clean Gravel
Dry Slope Wall 18 inches thick with 8 inch backing
Puddle
Embankment built in Six inch layers and rolled
Slope 2½ horizontal to 1 Vertical.
Note
For the Letters referred to in these Sections see Sheet B
TRANSVERSE SECTION ON DC
20 Inch Pipe for Drainage
Original Surface of ground
Embankment
Natural Earth
Slope 2 to 1